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TRAUMATIC OSTEOMYELITIS:  
THE USE OF SKIN GRAFTS—PART I

TECHNIC AND RESULTS

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DURING THE PAST TWO YEARS an extensive experience with the application of skin grafting to the treatment of osteomyelitis resulting from war wounds has been accumulated at Ashford General Hospital. This procedure is neither new nor original with us. Lord<sup>1</sup> reported Thiersch grafting of osteomyelitic cavities in 1902. Reid,<sup>2</sup> in 1922, published a concise report covering most of the aspects of the subject which we consider important. Armstrong and Jarman,<sup>3</sup> as well as Quick,<sup>4</sup> report the use, the latter over a period of 20 years, of a technic similar to that employed by us. Neuber,<sup>5</sup> in 1895, Lord,<sup>6</sup> and Beekman,<sup>7</sup> somewhat later, have written of the applicability of pedicle skin grafting to the arrest of this condition.

The above reports, collectively, have reference to hematogenous osteomyelitis, as well as to bone infection of traumatic origin. Nevertheless, skin grafting of osteomyelitic wounds has failed to come into the general use which we feel its effectiveness warrants.

One isolated skin grafting procedure has found reasonably wide acceptance and adoption. This procedure is applied to the indolent persisting recurrent superficial ulceration involving scar epithelium and underlying bone seen in old hematogenous osteomyelitis of the tibia. All scarred soft tissue and superficial unhealthy bone in the area is excised. An appropriate relaxing incision is made. The intervening flap is undermined and shifted to obtain *per primam* healing of the involved area, and the former site of the shifted flap is filled in by a free-skin graft.

One of the authors of this paper (R. P. K.) had been impressed with the latter procedure, and while stationed at another Army General Hospital had the opportunity of observing in three cases the effectiveness of free-skin grafting of granulating bone cavities of longer or shorter standing, which resulted from saucerization of osteomyelitic processes. The work to be



presented in this series of reports finds its background in the above observations and in the reported work of Converse<sup>8</sup> on skin grafting in war wounds. That author pointed out that regardless of the bacteriology and apparent degree of contamination of the wound, a "dressing" of skin often resulted not only in a considerable amount of apparently nonspecific benefit to wound healing but in a surprisingly high proportion of "take." In addition to the foregoing, we believe that this work owes great credit to the availability of the dermatome, as developed by Padgett. This instrument places within the grasp of the average surgeon the ability easily to obtain free-skin grafts of desired thickness in reasonably unlimited amounts.

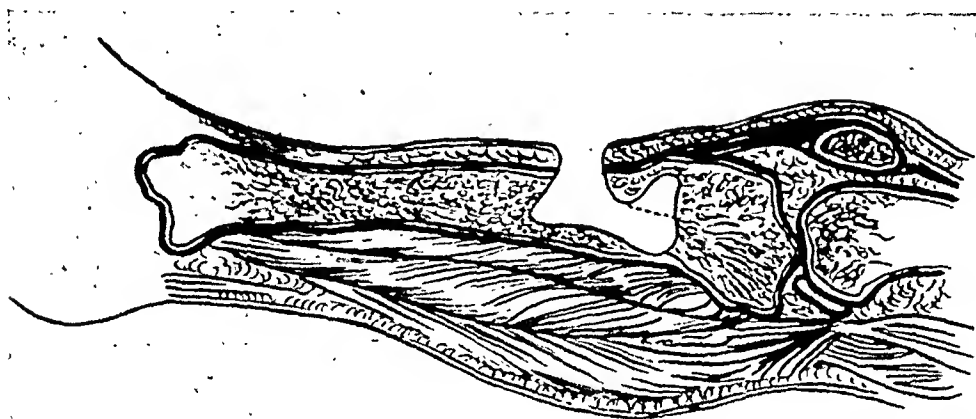


FIG. 1.—Cross sectional representation of wound not suited for skin grafting. The extreme difficulty of applying appropriate pressure to that portion of a skin graft above the broken line is apparent.

#### TECHNIC

The experience of two years with all representative skeletal structures except the spine and skull, and of approximately 100 osteomyelitic wounds has evolved a technic of wound preparation which at present we consider ideal.

First, every effort is made to improve the patient's general condition. This may require transfusions of whole blood and plasma. Meanwhile, necessary preliminary laboratory and roentgenologic studies are carried out, and local skin preparation, after bivalving the encasement, is begun. Unfortunately for completeness of data, adequate wound cultures are not available in many cases. This point is recorded not with pride but to emphasize our feeling that in this group of wounds individual attention to bacteriology is apparently unimportant. This view is subject to change and we hope to substantiate it or refute it following completion of more detailed studies.

Saucerization is then carried out. This has become an increasingly exacting procedure. As performed, it is analogous to débridement of a fresh wound. It has the additional feature that the wound topography must *approach* a saucer-shape. If this topographic ideal is sufficiently met to permit a satisfactory pressure dressing to be applied over the skin graft which follows, no additional healthy soft tissue is sacrificed. We do not hesitate to sacrifice

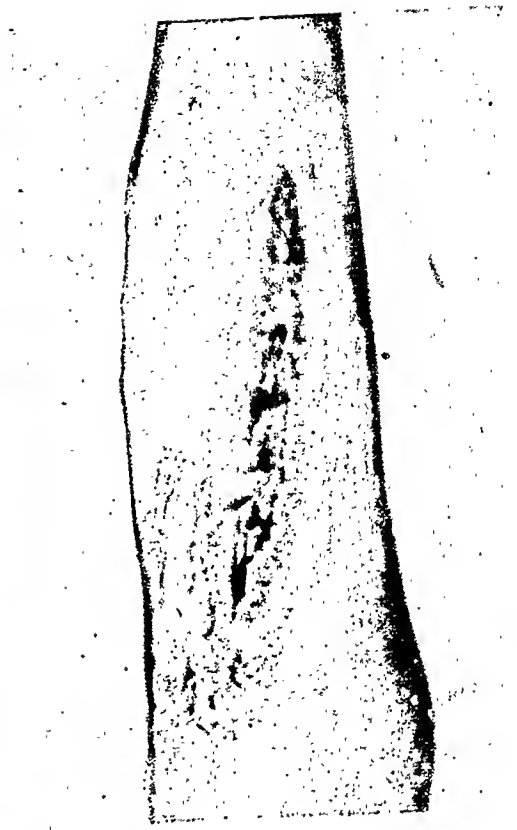


PLATE 1: A. Clinical photograph of right leg three months after shell fragment wounds.  
 B. Saucerized wound.  
 C. Completed skin graft 4 days after final saucerization.  
 D. Healing nearly complete.



bone, provided in so doing the surgically created bone weakness does not exceed that of the preëxisting "weakest link" caused by the pathology under treatment. This rule may be violated where one is not jeopardizing functionally essential stability of the skeletal structure, or when its violation is necessary to permit access to devitalized tissue. For the sake of completeness, it is recorded that great respect is held for the intactness of nerves and major arteries. Wound surgery is begun at the point of juncture of healthy and

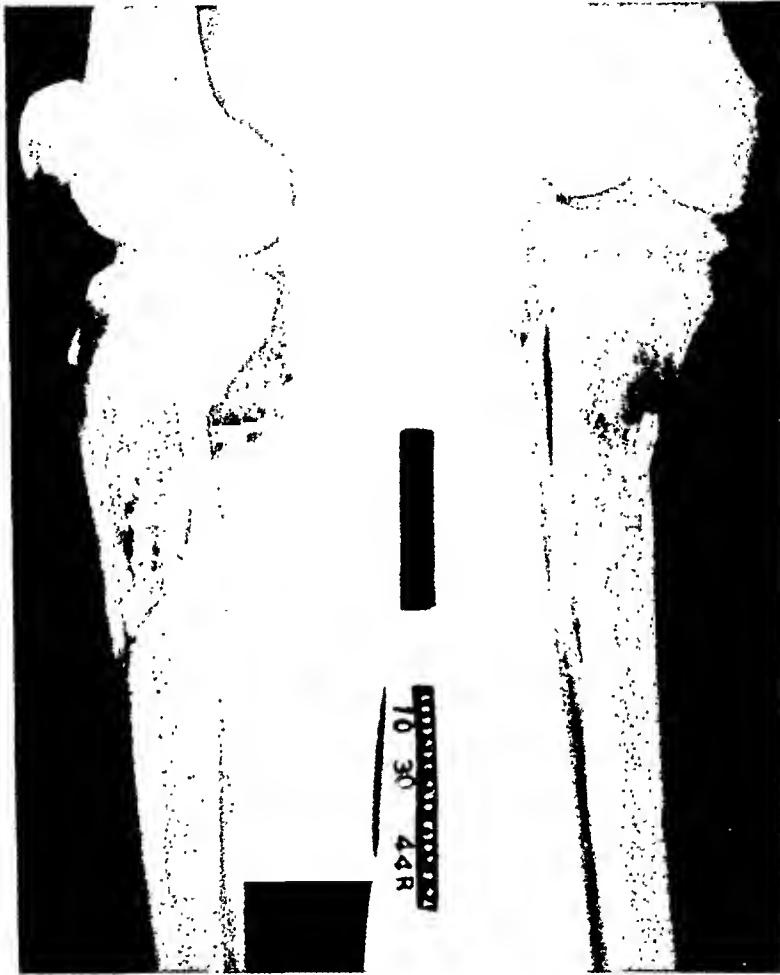


FIG. 2.—Case 1: Roentgenogram of right leg three months after shell fragment wounds.

unhealthy skin. A line of cleavage between scar tissue and relatively normal surrounding tissue is developed, followed down on one side to the depth of the wound, thence up the other side to the opposite edge. By following this plan it is often possible to accomplish a complete removal *en bloc* of all unhealthy tissue and of all foreign bodies. Any undesirable tissue not included is subsequently removed. If the skin edges which appeared healthy along the line of excision are fibrosed and scarred on the under surfaces, this scar is removed and skin mobilization back to healthy soft tissue is carried out. Any remaining skin whose vitality is questionable due to the presence of cyanosis or ischemia is further excised. Shaping of the wound to suitable topography (Fig. 1) for skin grafting is then carried out. During the course of this it is common to uncover further small sequestra and extrinsic foreign

bodies. Next, any remaining tissue which, though not frankly scarred, appears of low vitality, and in the judgment of the operator will contribute little to function, is removed. Finally, any tendon denuded of its sheath, or any exposed ligament which will not contribute to the anticipated function of its joint is excised. If such a structure is vital, an effort is made to cover it by shifting a flap of local healthy skin. Lacking this, the structure is sacrificed and subsequent reconstruction is planned.

The wound preparation as outlined above is considered absolutely necessary to satisfactory results. Its accomplishment necessitates careful and



FIG. 3.—Case 1: Roentgenographic appearance nine weeks after skin grafting.

frequently extensive surgery. Thus, the patient's general condition must be the best. The use of a tourniquet in suitable locations is often desirable to minimize otherwise uncontrollable blood loss. Feeling that tissue vitality must be always decreased by its use, we have omitted the tourniquet whenever it was considered safe to do so. Plasma infusions and transfusions of whole blood at operation are commonly necessary. In several severe cases, wound preparation has of necessity been accomplished in stages. The procedure followed in these cases is that of preparing the patient for both saucerization

## SKIN GRAFTING FOR OSTEOMYELITIS



FIG. 4A

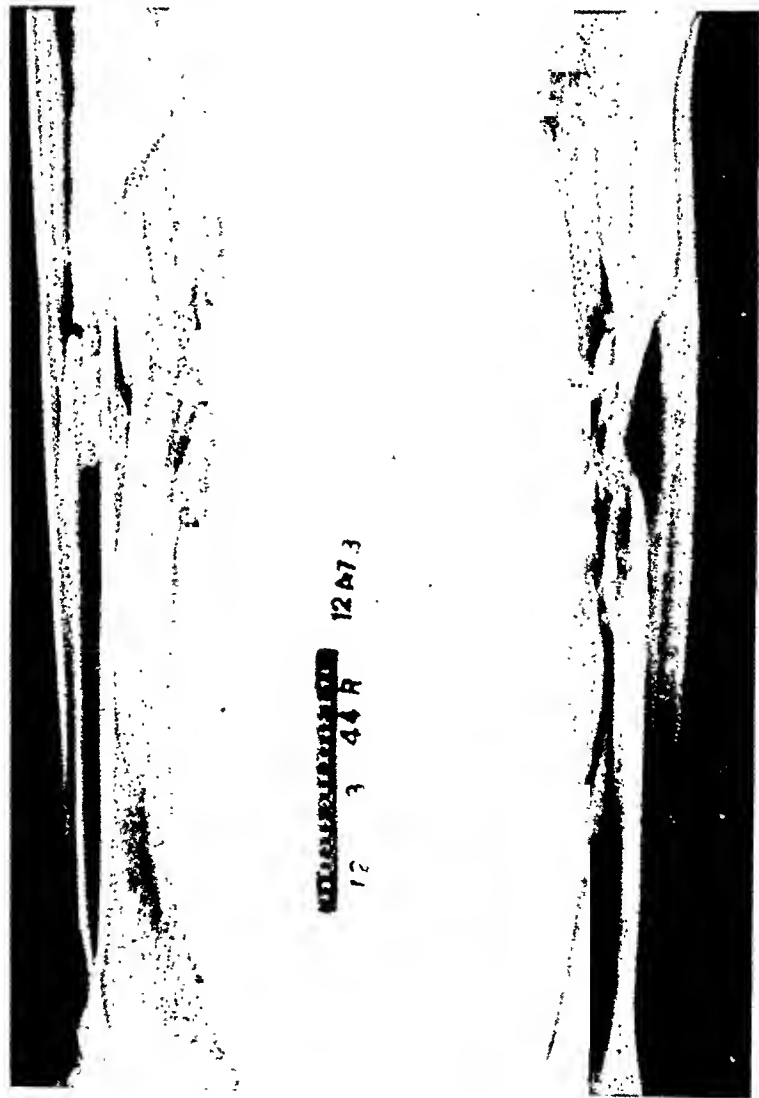


FIG. 4B

FIG. 4.—Case 2: Clinical photograph and roentgenogram of right leg two months after close-range bullet wound.

and skin grafting, and of carrying out further saucerization if the gross appearance of the wound is unfavorable for skin grafting. Where staged saucerization has been necessary, granulations developing in the area untouched since the first operation of the series may have become thick and edematous. In such instances it is our practice, after permitting the patient a rest of some two or three weeks, to "peel" the granulations from the wound as a final preliminary procedure. Thereafter, the wound is treated just as those in which only a single saucerization has been adequate.

Early in the development of this procedure an orthodox *Orr dressing* was applied to the saucerized wound prior to skin grafting. Our present treatment is fundamentally the same, but for two exceptions: We feel that fatty substances on the granulating bed may interfere with vascularization of the skin graft. The same is true of thick edematous granulations. Therefore, the postsaucerization dressing as now employed (Fig. 2) consists of a layer of fine-mesh bandage gauze made as wrinkle-free as possible, in direct contact with the tissues of the wound. Over this is packed a suitable mass of mechanics' waste, to permit of applying, by means of an Ace bandage, as much pressure to the wound as can be made without embarrassing circulation at more distal points. The latter can be minimized by extending the area over which pressure is made in the extremity to the base of the toes or fingers. To permit swelling, with minimal increase in pressure, a thick layer of sheet wadding is wrapped on over the Ace bandage. Following this, plaster immobilization, as for orthodox Orr treatment, is employed. In addition to the dressing as described, more recently a single Carrel's tube has been incorporated into the mechanics' waste portion of the dressing and brought out through the encasement. One per cent solution of acetic acid, in amounts proportionate to the size of the wound, is used as an irrigant through this tube at four-hour intervals. Thus, contamination by *B. pyocyaneus* and *B. proteus* is reduced.

Our early practice was to wait for periods as long as one month between saucerization and skin grafting. *This interval has been progressively shortened*, with increasingly beneficial results. At the present time, skin grafting is usually performed *four days after saucerization*. Simultaneous sequestrectomy and skin grafting have been undertaken on three occasions, with good results. Where adequate saucerization is performed it is preferable to wait three to four days to permit the formation of granulations on relatively avascular cortical bone. Moreover, uniformly healthy granulations however thin, visible after four days of pressure dressing, are an index of a healthy wound likely to respond favorably to grafting.

Immediate local preparation for skin grafting consists merely of bivalving the encasement prior to the patient's going to surgery, and of preparing appropriate donor sites for skin. Sometimes three or four drums of skin have been necessary to provide adequate coverage.

On a flat surface a skin graft can be subjected to some tension without reducing the possibility of applying uniform pressure of a suitable degree over the wound. On the uneven, and often complex, surfaces of these wounds,

tension must be completely eliminated from the graft to permit the possibility of attaining the ideal of uniform pressure at all points.

By resorting to more radical surgery, with removal of a greater amount of healthy tissue, it might be possible to obtain a wound the outline of which did not entail such great difficulty in proper application of pressure to the graft. Wrinkling must be avoided as much as tension. By time and care, and removing "V"-shaped pieces of skin at strategic points about the graft,

FIG. 5A



FIG. 5B

FIG. 5.—Case 2: Saucerization was carried out in three stages over a period of six weeks, followed by "peeling" of granulations three days prior to above views. (A) The saucerized wound immediately prior to grafting. (B) The graft sutured in place. Note that in the latter view and in Cut C on color plate the grafts fall of their own weight into the deep recesses of the wounds.

a piece of patchwork, fitting the complicated surfaces of the wound is obtained. Along the secondary suture lines, necessitated by this fitting of the graft, untied running sutures are placed with one end left long. These are withdrawn when the graft has become firmly adherent to its bed. The edges of the graft are sutured to the skin edges with nonabsorbable material. Because of satisfactory results from mechanics' waste as a pressure medium, we have employed a stent in only one case in our series.

Occasionally the open medullary cavity presents at one end of the depth of the saucerized wound. Thus, a gap of small diameter may exist in the granulating bed at this point. This situation is met by making a vertical slit in the portion of the graft overlying the gap. Thus, contact with the bed is



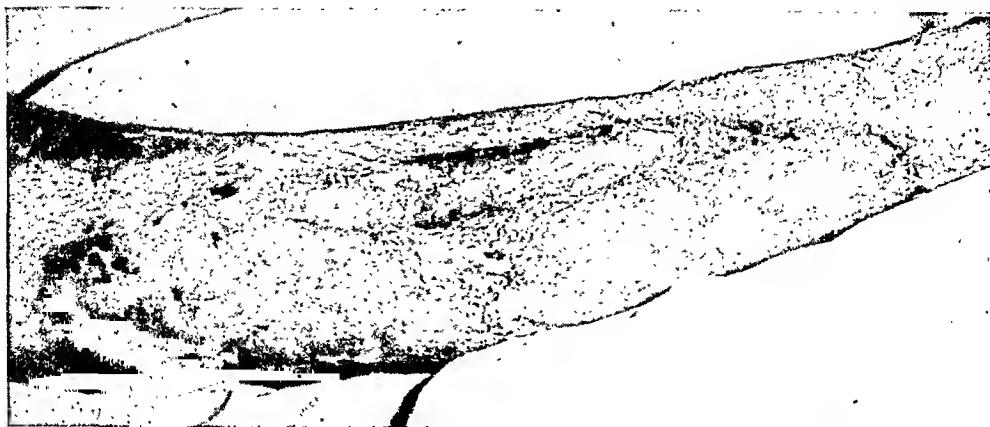


FIG. 6A



FIG. 6B

FIG. 6.—Case 2: These illustrate (in A) the appearance of the graft on removal of dressing five days after operation, and (in B) the roentgenographic appearance 20 days after skin grafting.

maintained, delayed filling of the gap by granulation is presumed to follow, and it is finally closed by secondary epithelization.

With two exceptions the postoperative dressing is essentially the same as that applied after saucerization. Boric acid gauze instead of plain fine-mesh gauze is preferred in contact with the graft. The pressure applied by the Ace bandage is reduced to the amount suitable for any skin graft, with due allowance for the depth of the cavity. Better results have been obtained when the pressure dressing is irrigated either with a weak acid solution or with penicillin 1:250. This is especially true of the wounds in which considerable drainage develops.



FIG. 7.—Case 2: Appearance of wound nine weeks after surgery. Healing still not quite complete.

In the latter group of wounds, as early removal of pressure dressings as possible prevents loss of graft by maceration. We have found it safe to remove pressure dressings as early as *four days*, but prefer to leave them longer when a minimum of exudate is apparent. An odorless dressing suggests minimal exudation. Rarely is a pressure dressing left in place for more than *six days*.

On removal of the pressure dressing, wound cultures are taken, and gauze compresses are loosely inserted into the wound and kept wet with saturated boric acid solution. Beyond this, the graft is left exposed as much as possible, since maceration is a hazard until such time as all drainage ceases. If, by culture, the organism is penicillin-sensitive, and if *B. proteus* or *B. pyocyaneus* are not present, local penicillin is used instead of boric acid. Should *B. proteus* or *B. pyocyaneus* be one of the contaminants, the compresses are kept moist with 1 per cent acetic acid until these organisms disappear. Such management of the wound is continued until complete epithelization has occurred.

Replacement of free grafts by a variety of pedicle procedures has been successfully carried out in a considerable number of these patients. It is intended to discuss in a later paper the various aspects of this semifinal phase of the treatment of traumatic osteomyelitic wounds. In the course of replacing the free grafts it has been possible to obtain *en bloc* biopsies of the orig-

inal graft, the underlying bone, and the intervening tissue, the study of which has been the source of considerable interest.

### RESULTS

Patients treated have been young male adults suffering from traumatic osteomyelitis, almost exclusively due to projectile wounds. Traumatic osteomyelitis has been considered to exist whenever there is purulent drainage from a wound which communicates with bone presenting roentgenographic evidence of infection or fracture. Eight weeks after free-skin grafting there is usually complete epithelial covering of the entire saucerized wound surface, the proportion of relatively normal skin to scar epithelium depending largely upon the amount of initial "take." A large group of cases, with varying degrees of bone involvement, have been treated by this method. The results have been almost uniformly beneficial. In only two cases has complete loss of the graft ensued. It has been necessary in only two cases surgically to remove further sequestra for progressive healing to occur. Cases have been under observation for periods as long as one year after skin graft, the average period having been approximately seven months. The cases analyzed below were selected purely on the basis that they most obviously met our criteria for osteomyelitis, and, as a group, were of more than average severity. Surgery upon these cases was carried out by eight different operators. Results were evaluated in 43 patients presenting 45 osteomyelitic wounds upon whom 47 skin grafting procedures were performed. Criteria for evaluation and results were as shown in Table I.

Of the poor results, two occurred on successive grafts in the same wound. One poor result was so classified in a patient with 50 per cent initial "take" from whom the first graft was completely removed and a new graft substituted to accelerate healing. Another poor result was obtained before we learned the necessity of a tensionless fit of the graft to the bed. This case forcefully demonstrated this necessity. Another poor result was obtained where the obviously futile attempt was made to get skin to grow on completely exposed tendon. Another case was classified as poor where a good "take" followed by infection necessitated resection of the graft and further removal of bone deep in the shoulder girdle. In a sixth case, classified as poor, the free graft has served its purpose well, in that an almost completely healed wound with a few small, cleanly granulating spots has resulted. In this case, replacement by full-thickness skin is being carried out to permit subsequent arthrodesis of the knee joint. A seventh case failed because adequate vascularity was not surgically obtainable. The circumstances attending the poor results in the remaining four cases are not clear.

The sole complication was quite severe. Ten days after a shotgun wound of the wrist, simultaneous saucerization and skin grafting were performed. Moulded plaster pressure was employed over the skin grafts. Probably due in some way to this form of pressure, an apparently low grade infection developed between the deep and superficial fascia. The patient ran a markedly septic course beginning ten days after operation. Blood cultures

showed *Staphylococcus aureus hemolyticus*. The response to penicillin was favorable. This form of dressing has been discontinued.

Reports by illustration of two severe cases, each involving the tibia, are presented in Figures 2, 3, and color cuts and in Figures 4 to 7, respectively.

TABLE I

Excellent: 90 per cent or better "take," with progressive healing.  
Good: 75 to 90 per cent "take," with progressive healing.  
Fair: Less than 75 per cent "take," with progressive healing.  
Poor: Less than 40 per cent "take," or regrafting necessary.

On the basis of these criteria, the results in the cases considered were:

Excellent—24 per cent.  
Good—28 per cent.  
Fair—24 per cent.  
Poor—24 per cent.

#### SUMMARY AND CONCLUSIONS

There have been occasional reports of the successful application of skin grafting in the treatment of osteomyelitis of hematogenous and of traumatic origin for many years. This procedure has failed to gain wide acceptance. It has been successfully carried out by the technic as described for over two years at an Army General Hospital. This is a safe form of surgical treatment. Beneficial results can be anticipated in the majority of cases, with loss of little more than skin in the failures. The use of skin grafting in traumatic osteomyelitis has failed to receive the general adoption its effectiveness warrants.

The authors wish to acknowledge their indebtedness to the medical officers assigned to the Orthopedic Section, Ashford General Hospital, from its opening to the present time; for use of cases whose surgical care they carried out; to Captain F. B. Hall and Technician Fifth Grade Joseph Jackson for their photography; finally, to Colonel D. C. Elkin, Chief of Surgical Service, for constant encouragement, suggestions, and help.

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# EXPERIENCES WITH 156 PENETRATING WOUNDS OF THE HEAD

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THE PURPOSE OF THIS COMMUNICATION is to present experiences with 156 consecutive craniotomies performed for penetrating wounds of the head in a Forward Hospital. Simple lacerations of the scalp, no matter how extensive, are not included in this series. However, they should be treated by the Neurosurgical Service. On five occasions depressed compound fractures, which were not revealed roentgenologically, were found during adequate scalp débridements. Scalp lacerations were treated by wide shaving, thorough cleansing with white soap and water, iodine or metaphen, excision of devitalized tissue, introduction of sulfanilamide powder, and closure with two layers of silk, without drainage. No complications were noted. Lacerations should be sutured only when facilities and personnel are ready to proceed with an intracranial operation.

In this series of 156 operations for penetrating wounds of the skull, the dura was found to be intact in 19 cases, and lacerated or penetrated in the remaining 137.

## LOCATION OF ENTRANCE WOUNDS

Frontal.....	50
Including frontal sinus.....	18
With orbital injury.....	8
Frontoparietal.....	8
Temporal.....	14
Mastoid.....	3
Parietal.....	59
Bilateral vertex.....	4
Bilateral, two wounds.....	1
Parieto-occipital.....	6
Occipital.....	16
Bilateral gutter.....	3
Sphenoid.....	2
Wound through cheek.....	1
Suboccipital.....	1
(in foramen magnum, through neck)	
Total.....	156

## MAJOR VESSEL INVOLVEMENT

Middle meningeal artery.....	15
Major venous sinuses.....	11
Total.....	26

This series includes 14 civilians injured in combat zones, and as a result of this, the ages vary from one to 65 years; the majority were soldiers in the third and fourth decade of life.

The average time-lag between the time of injury and admission to the hospital was 12 hours, although the patients were seen anywhere from one to 72 hours. Experiences with transportation of these patients confirm obser-

vation of others (Ashcroft of the British Army and, as reported in the ANNALS OF SURGERY, July, 1943, by Colonel R. A. Money and Lt. Colonel T. Y. Nelson) that they, as a group, transport well prior to operation but poorly for four or five days postoperatively. In view of this the operative procedure should not be undertaken unless really adequate neurosurgical facilities are available. However, the opinion expressed by some neurosurgeons that these patients should be transported to a base is not agreed with because this may necessitate a delay in surgery of from 24 to 72 hours, or more. Many of these cases show rapid progression of signs and symptoms, and would not tolerate the delay necessitated by evacuation to a Base. Intracranial wounds have much in common with wounds of other parts of the body. After proper preparation of the patient, the earlier the procedures are undertaken the better the end-results, both as to mortality and return of function. It is readily admitted that many of the cases that would die in transit, are those with very little hope for a good return to a fairly normal existence. However, a few of these cases have produced pleasant surprises. The Forward Evacuation Hospital is the ideal place for this type of surgery, for it presents the most forward site where adequate facilities are available. Neurosurgeons, who have worked with field hospital platoons set up near Clearing Stations, have expressed the opinion that such installations are "no place for neurosurgery." While it is true that Field Hospitals are equipped to do first priority surgery—penetrating wounds of the abdomen and chest, very severe extremity wounds, *etc.*—it is also a fact that, as their facilities are limited, head cases frequently have to wait. Because these patients do stand transportation better before than shortly after operation, and because the Field Hospital moves much more frequently than the Evacuation Hospital it would seem sounder surgical policy to send such cases on to the Evacuation Hospital at once. The absence of a roentgenologist in the Field Hospital is another cogent reason for evacuating head cases to a larger hospital installation before definitive surgery is undertaken.

Upon admission to this hospital the patient is taken to the preoperative tent. Here a complete physical examination is made, and adequate treatment for shock or impending shock is instituted. A thorough neurologic examination is made, with the aid of the neurologist. His opinion is very important, not only to record the evidence of damage, but also as a basis for follow-up study of the patient. When the patient's shock is under control, and not before, roentgenologic studies are made and carefully studied with the roentgenologist. The value of stereoscopic exposures is great. However, many of the patients are unable to cooperate and such films may be impossible to obtain. While still being prepared for operation, the patient is given preoperative medication. This is composed mainly of barbiturates, morphine and atropine or scopolamine. There have been no untoward reactions in the administration of morphine in doses up to 10 mg., and it has been a definite aid in the induction of the anesthesia. In the last 40 cases, penicillin has been administered preoperatively as a routine. Prior to the use of penicillin, sulfa-

diazine was administered intravenously in all cases where operative delay was necessary.

In this series, novocaine infiltration, sodium pentothal and endotracheal ether were employed. Local novocaine was found unsatisfactory because of the psychic trauma, and the inability of the patient to coöperate. In addition, the presence of multiple wounds in 103 cases strongly tipped the scales in favor of general anesthesia. In the first third of the series, sodium pentothal was used in the majority of the cases. Although there were no untoward results, that is not the anesthesia of choice, for the following reasons:

1. The majority of the procedures are lengthy, especially so in patients with multiple wounds.
2. The patients are often in the face-down position and the control of respirations is more difficult.
3. In Lt. Col. Beecher's excellent recent anesthesia report,\* sodium pentothal was shown to be more lethal than ether.
4. Patients given sodium pentothal take much longer to react than those who have had ether, making postoperative procedures and observations more difficult.

Ether is not only the safest anesthetic, but the use of an endotracheal tube has obviated the danger of aspiration of blood in procedures involving the face, antrum, and frontal sinuses. This procedure keeps the patient under complete control during the intracranial operation and in the various positions required for the surgical treatment of multiple wounds.

It is obvious that adequate instruments must be on hand if the procedures are to be satisfactory. Front line Ordnance Companies have been most helpful in making some instruments, designed by the authors. These include unusually long, narrow, lighted retractors, a specially designed long, narrow suction tip, to aid in the removal of deeply driven small bone chips, a long seven-inch magnet tip for the removal of metallic foreign bodies, as well as a good scalp retractor. By the use of a padded baseball mask, attached to a steel plate by metal arms, a satisfactory head rest was made.

While the patient is being anesthetized, plasma is started, and at least 500 cc. of whole blood is on hand for use during or after the operation. When the patient is asleep, the scalp is completely shaved, washed, prepared with antiseptics, draped in the usual manner, and then the wound is excised, but the removal of skin is extremely conservative. Adequate exposure is accomplished usually by linear extensions and is guided by roentgenographic findings. With a "tripod incision" poor healing is common, and this incision is undesirable and unnecessary. By carefully undermining the scalp, one can usually close the wounds without difficulty. Only one case in this series demanded a counter incision for closure, and that was due to the extreme loss of tissue. The periosteum having been carefully lifted (for it may be used as a graft) one or more bur holes are made in normal bone adjacent to the damaged area,

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\* Medical Bulletin of North African Theater of Operations.

down to intact dura. The destroyed bone is removed by carefully rongeur around it. Herniated brain tissue is removed by suction or cautery and bleeding vessels controlled by silver clips before further exploration is attempted. Wide removal of bone for proper exposure cannot be overemphasized.

Despite the emphasis in civilian practice on the "elevation" of depressed fractures, only one case was found suitable for elevation. This was a frontoparietal wound from a direct blow of a rifle butt. In most penetrating wounds in combat zones, the involved bone is so comminuted and the fragments so scattered, that elevation and preservation is out of the question. Extradural hemorrhage is usually found in this type of wound, but is not very severe, for the depressed fragments tend to control bleeding. Tears of the middle meningeal artery were encountered in 15 cases, the hemorrhage being controlled by clips, cautery, and in two cases by plugging the foramen spinosum with cotton.

In 19 cases the dura was found to be intact. Even if the color is normal, lack of pulsation is considered a good indication for subdural investigation. Lack of dural pulsation led to opening of the intact dura in 14 cases, and definite subdural pathology was encountered in every case—there were three subdural hydromas and one intracerebral hematoma. The remainder showed either macerated brain or hematoma. The dura was closed after normally pulsating brain was visualized. In the penetrating wounds damaged dural margins are excised very conservatively, the bleeding vessels are controlled, and the opening in the dura is enlarged by radiating or curved linear incisions to provide sufficient exposure of the tract. The tract is débrided by suction under direct vision—with the use of proper size lighted retractors—until firm brain tissue is found. All bone chips must be removed. Since roentgenograms do not show all these, especially minute ones, nothing can take the place of thorough inspection of the tract under direct vision. A useful maneuver here also, is the gentle insertion of the little finger in the tract, for bone fragments, no matter how small, may be noted. The removal of the metallic foreign body is advisable, under direct vision, for that completes the débridement of the tract. Most neurosurgeons agree that missed bone chips provide the ideal nidus for infection and most secondary brain abscesses may be attributed to them. In view of this, cultures of the bone chips were made, with the help of one of the Field Medical Laboratory units, and showed positive bacterial contamination in every case. Although most surgeons advise the removal of metallic foreign bodies, if easily accessible, they maintain that their presence does relatively little harm. Recently, the culturing of these metallic foreign bodies has found them to be covered with a positive bacterial contamination. The long, previously mentioned, magnet has been used successfully in gently removing the foreign body under direct vision, after the tract has been débrided by suction directly to the foreign body. In long tracts, especially where the foreign body has crossed the midline, it has been our policy to débride, by suction, the complete length of the tract. Direct vision should be obtained as far as possible. The use of a soft rubber catheter



in very long tracts is preferable to the rigid suction tip. The long tracts should be débrided cleanly and completely, for the amount of brain damage may be all out of proportion to the size of the wounds. Recovery and return of function has been smoother, quicker, and better when all devitalized tissue is removed.

Where the cerebral ventricles have been involved, the mortality has been high in the past. Radical surgery is still necessary, and has reduced the mortality rate. In five ventricle wounds there were two deaths, and these are in the category of long tract wounds, which in themselves carry a high mortality.

Venous sinuses were involved in 11 cases. The wounds ranged from a small tear to one that was completely divided (the superior sagittal in its posterior third) and necessitated ligation. All the others were patched successfully by muscle stamps.

The incidence of injuries through the frontal sinuses and orbit is surprisingly high—26 cases having been seen, of which eight were orbital. The treatment which has proved completely satisfactory is the radical removal of the mucous membrane and the walls of the sinus, thus obliterating them. All injuries through the orbit were done in conjunction with the ophthalmologist. There were three other cases involving the air sinuses, one of the antrum and two of the mastoids.

In the closure of the wounds, the one factor that supersedes all others is the closure of the dura. After complete hemostasis has been attained in the tract, the problem of local chemotherapy arises. In the first part of the series one to three grams of sulfanilamide were inserted in the tract. Recently, this has been abandoned in favor of penicillin, 7,500 to 20,000 Oxford units injected by hypodermic needle after the dura closure. The dura, in most cases, is so damaged it cannot be closed without resort to a graft. Fascia lata was used in a few cases, especially in the frontal sinus wounds, but this was given up because of the added surgery and the availability of temporal fascia, pericranium or galea, which is very satisfactory. In the last 33 grafts, cadaver dura has been used, with no early untoward results. It is kept on the operating table, and may be immediately cut to the desired size. Being tougher than pericranium, suturing is easier. This method is still on trial and late reports on these cases, which are being anxiously awaited, will prove or disprove the wisdom of this procedure. The dura is preserved by putting it in 10 per cent formalin for 48 hours. After thorough washing in water, it is placed in 70 per cent alcohol, where it may stay indefinitely. Before using it is washed thoroughly in saline.

The scalp is closed in two layers, with one layer in the galea and one in the skin. Three layers are used when the temporal muscles are involved, with the additional layer approximating the muscles. Silk is employed entirely. Drains were employed in two cases in which there was a long time-lag and excessive contamination. The wound is then covered with a vaselined sterile dressing and kept in place with a stockinette hat. Occasionally, when the bone defect is large, a light plaster of paris cap is used.

Better postoperative care is secured by having the patients in one ward, with sufficient personnel, including specially trained and interested nurses and medical corps men. Oxygen by nasal catheter is given routinely to all patients for at least 12 hours. A suction machine is present at all times for any postoperative emergency. The fluid balance is maintained, and 2,500 cc. is usually given daily. Adequate supportive blood and plasma are given when deemed advisable. Sulfadiazine was given intravenously if not tolerated by mouth, but this has been supplanted recently by the use of penicillin, 200,000 Oxford units daily up to a total of 2,000,000 units. Sedation used has been mainly the barbiturates and paraldehyde. Morphine and codeine have been used cautiously in cases complicated by painful additional injuries. Spinal taps have not been done routinely. They are useful in the control of persisting headaches. Sutures are removed from the third to the sixth day depending upon position of wound.

Approximately two-thirds (103) of these patients with penetrating head wounds had other wounds in addition. Forty-six had compound fractures varying from small injuries of the fingers to severe comminution of the humerus or femur. There were three cases with penetrating chest, and two with penetrating abdominal injuries. Fifty-seven had soft-tissue penetrating or perforating wounds. The intracranial procedure may follow the treatment of the other wounds since, with careful observation, the majority of head wounds may "wait" for surgery better than extensive abdominal, chest, or extremity wounds. In certain cases, stage procedures have lowered the mortality. With the other wounds attended to, the patient is observed and prepared with good supportive treatment and liberal use of blood before the intracranial procedure is attempted. Patients with the combination of bad compound extremity wounds and penetrating head wound do uniformly poorly unless this surgery is done in stages—nine such cases were done in two stages, with one death, and five cases done in one stage, with three deaths. The addition of penicillin to our armamentarium should make this two-stage policy safer. In the postoperative care, dual responsibility of the patient with multiple wounds is unsatisfactory, and if it is possible for a general surgeon, trained in neurosurgery, to assume complete control of such a patient, the best results are usually obtained.

In this series, there was no attempt at the selection of cases, except in times of heavy fighting when there might be, and sometimes were, several head cases awaiting operation. At these times, priority was given to the cases which presented the best chance for survival, with return of function. In addition to the 156 operative cases reported, there were 34 other penetrating head wounds seen in our Receiving Tent. Of these, 33 died very promptly, and the other was evacuated to the rear. He had a facial wound of entry with a foreign body of considerable size lying beside the sella turcica. He was in no condition for major operative procedure, even if it were indicated, which is doubtful. He was evacuated of necessity when the hospital moved. One case had both an abdominal and head injury, and

failed to survive the abdominal procedure. The other 32 cases had massive injuries, were in deep shock, and were classed as moribund. Most of these died within six hours after admission. Thirty of these cases were seen in the early days on the Anzio Beachhead, where close proximity to the front made possible the reception of patients who ordinarily would have died before reaching an Evacuation Hospital.

In this series there were 17 deaths, an operative mortality of 10.8 per cent. This includes one case who was sent out during an emergency evacuation, and who was moribund at the time. The follow-up of these patients has been very satisfactory. In the majority of cases the patients remained in our hospital long enough to determine their status fairly well. The neurosurgeons in the rear echelons have been most kind and coöperative, in returning self-addressed V-mail letters sent to the rear with the patients. This informal method has given better results than complicated neurosurgical forms which other surgeons state have given a low percentage of return. There have been follow-up reports by letter of 90 of these cases, and, in addition, 20 others in the base hospitals were seen personally. The operative mortality is influenced by the fact that most of the patients are young and vigorous. In a considerable portion of these postoperative deaths, injuries other than the head injuries were a large factor.

The most serious postoperative complication encountered, resulted from the unfortunate bombing of our hospital, during which a fragmentation bomb landed beside the ward in which the head cases were housed. As a result of bomb fragments, one of the postoperative head cases required a major chest procedure, two required major amputation, and the remaining nine were wounded again. Fortunately all survived the additional injury.

A brief discussion of the patients who died in our hospital following operation follows:

**Case 7.**—A soldier, age 28, was admitted nine hours after a bullet had pierced his right frontoparietal skull. Unconscious and paraplegic. B. P. 80/0, pulse 120. He was given plasma, 3 units, and whole blood 1,500 cc. Three hours later operation revealed large bursting fractures of the entire vertex, with considerable brain damage in both parietal lobes. Never responded, and died 15 hours postoperatively. This type of case carried a grave prognosis and, during busy periods, more favorable cases should be done first.

**Case 17.**—A soldier, age 24, entered ten hours after being wounded. He had multiple penetrating wounds of the head, chest wall, both arms, both legs, and buttocks. B. P. 80/0, pulse very rapid and weak. Was semicomatose and in severe shock. Had 6 units of plasma and 1,200 cc. of whole blood. Roentgenologic examination showed a comminuted fracture right frontoparietal skull, with indriven bone fragments; comminuted fractures left femur and all bones of left elbow. Metallic foreign bodies in left scapula, chest wall, buttocks, and both thighs. Due to the position of the head wound and his lack of improvement, operation was started because it was felt he had a laceration of the middle meningeal artery. This was found cut; controlled by silver clip and cautery. Craniotomy was completed and remaining wounds were débrided and cared for in the usual fashion. However, signs of early gas infection were found in the wounds of the buttock and left thigh, and despite all antigas and supportive treatment, including 2,000 cc. of whole blood, patient died 72 hours after operation. Penicillin was not used as it

## PENETRATING WOUNDS OF HEAD

was not available, but probably would not have helped, as autopsy revealed massive gas infection which had already spread into the retroperitoneal recesses.

**Case 24.**—A soldier, age 22, arrived 21 hours after shell fragment had penetrated the right parietal skull. Unconscious, B.P. 60/30 and pulse 150. Plasma 4 units and whole blood 1,000 cc. were given. Roentgenograms revealed a punched-out area in right parietal skull, with three small metallic bodies in the base of the right hemisphere. At operation, tract was thoroughly cleaned as far as, and into, the lateral ventricle, from which two foreign bodies were removed. Despite oxygen, blood, plasma, he died 62 hours postoperatively, never having responded at all. Autopsy showed severe brain damage with the remaining foreign body imbedded in the floor of the ventricle.

**Case 31.**—A soldier, age 21, had had a small penetration of the left frontal skull, with slight damage, and was in excellent condition upon his return to the ward from the operating table. He happened to be one of the early cases on the Anzio Beachhead, just after the hospital had been set up. The nurses were not present during the early part of this invasion, leaving the hospital 50 pair of hands short of help. At this time there were many sick patients on the ward, when a very severe air raid began, and in the excitement the patient was overlooked. He was found dead one hour postoperatively, probably due to aspiration. It was felt that he would have had a complete recovery.

**Case 37.**—A soldier, age 28, entered four hours after being wounded. He had a traumatic amputation of the right leg just below the knee and another shell fragment had penetrated the right frontal skull. B. P. zero, pulse exceedingly rapid and thready. Tourniquet was left in place, and after 6 units of plasma and 1,500 cc. of whole blood the general condition appeared good enough for surgery. Roentgenograms had shown a depressed fracture right frontal area, with bone chips and foreign body driven into the right frontal lobe. Near the completion of the craniotomy his general condition became too poor for further surgery, so a physiologic amputation of the leg by tourniquet was decided. One thousand cubic centimeters of whole blood and 2½ units of plasma were given, but the patient died three hours later. Death occurred suddenly and unexpectedly. Postmortem examination failed to show any other cause for death.

**Case 38.**—An unknown British soldier was admitted unconscious, with a right hemiplegia. Pulse 64 and B. P. 120/80. Left pupil was enlarged and fixed. Roentgenograms showed a huge foreign body in floor, or vicinity of, the third ventricle, with a punched-in area to the left of the sagittal suture in frontal region, with bone chips strewn along path of missile. Three units of plasma and 500 cc. of whole blood were given before operation. Patient died 60 hours later, never having regained consciousness. Autopsy showed severe brain damage, with the foreign body in the floor of the third ventricle.

**Case 49.**—A British grenadier, age 28, was admitted unconscious, with a right hemiplegia. Had a bad laceration over the left occipitoparietal scalp, with other penetrating wounds of the right buttock and thigh. B. P. 90/64, and pulse 80. Roentgenograms showed the foreign body in the scalp, but no bone defect was noted. Two units of plasma were given. Pulse began to slow and débridement of scalp was done. Investigation of the scalp revealed a depressed fracture, which was then explored. The dura was intact, but a subdural hematoma was found over the left motor strip, with considerable brain damage. Patient died 24 hours later and postmortem examination failed to reveal any further pathology.

**Case 52.**—A British soldier was brought to the hospital six hours after a 30-caliber bullet had pierced left frontal skull. Unconscious, with a good pulse and B. P. Roentgenograms showed bullet to be in the right parietal area. Three units of plasma and 500 cc. of whole blood were given, and the operation was started six hours after admission. The tract was cleaned by suction as far as the midline, and all bone fragments were removed. Despite supportive treatment patient died 30 hours later, never having recovered consciousness.

**Case 57.**—A German prisoner, unconscious, with spastic paralysis of all extremities. Had penetrating wounds right antrum, right shoulder, and right thigh. Several metallic foreign bodies were seen roentgenologically in the vicinity of the pituitary gland. After 2 units of plasma and 500 cc. of whole blood, the tract was partially cleaned out, through the antrum wound. Twenty-four hours later lumbar puncture revealed a pressure of 400, and when repeated in six hours was found to be 200. Patient died next day, never having regained consciousness. Autopsy revealed the foreign bodies imbedded in the cerebral peduncles, with marked damage of the surrounding brain tissue.

**Case 62.**—The patient, age 24, was injured six hours prior to admission, was unconscious, with a right spastic hemiplegia and a left facial paralysis. Had a wound left parietal area, with a large brain herniation. Pulse 80, B.P. 110/70. Foreign body and bone chips were seen roentgenologically in the left parietal lobe. Six hours later, after 2 units of plasma and 500 cc. whole blood, craniotomy was performed. Condition seemed good postoperatively, and upon arrival at the ward tent, but he stopped breathing, and despite all methods of resuscitation he was pronounced dead.

**Case 65.**—A British grenadier was admitted two hours after having received a penetrating wound of the left frontal skull. He was unconscious, and had a left hemiplegia. B. P. and pulse were good. Roentgenograms showed a comminuted fracture left frontal skull, with metallic foreign body in the right parietal lobe. Three hours later, after plasma and blood, craniotomy was performed. The tract was cleaned as far as the midline, but the brain did not pulsate normally. Investigation was continued but no further pathology was found. Dura was closed. Twelve hours later pulse slowed considerably, respiration faltered, and patient had a severe brain herniation, dying immediately. This case proved the vast importance of having the brain pulsate normally before closing the wound. Since this time a wound was never closed unless the brain did pulsate normally. On one occasion an intracerebral hematoma was found in view of this policy.

**Case 70.**—A Scotch guard, was admitted unconscious, two hours after shell fragment had penetrated the right occiput. He had a spastic hemiplegia on the right. Pulse 80; B. P. 150/80. Roentgenograms showed a comminuted fracture right occipital skull, with a foreign body in left parietal area just beneath the inner table. Six hours after admission, following blood and plasma, craniotomy was performed. The tract was cleaned to the midline and a counter incision was considered. This was impossible because the general condition of the patient became very poor. Patient never responded, and died in 72 hours. Postmortem examination revealed massive brain damage, especially in the left parietal lobe.

**Case 115.**—A soldier, age 23, was comatose and nonresponsive on admission, with a pulse of 72 and B. P. 80/40. He had a penetrating wound of the left temporal skull, with comminuted fracture there, and the foreign body, seen roentgenologically, lay in the posterior portion of the left parietal lobe, probably against the falx. He had a right facial paralysis and a flaccid paralysis of the right arm. After preoperative supportive treatment, craniotomy was performed, and the tract was cleaned as far as the falx. The foreign body was never found and appeared to have slid along the falx. Patient never responded, and despite all supportive measures, including the placing of a large suture in the tongue to prevent its falling back in his throat, he died 65 hours postoperatively, with cardiac failure. Autopsy showed marked brain damage of the left parietal lobe with the foreign body having slid posteriorly along the falx. This death brought an end to a successful series of craniotomies—45 without a death—in the previous 60 days.

**Case 127.**—A soldier, age 32, entered with a large brain herniation in the left parietal area, due to a penetrating wound by a 9-Mm. bullet, and another penetrating wound of the abdomen. Unconscious, with a right hemiplegia. Pulse and B. P. were good. Roentgenograms showed a comminuted fracture left parietal skull, with bullet in the parietal lobe. Craniotomy was performed, and perforations of the small bowel were

closed. The next morning, with additional blood and plasma, craniotomy was performed, and the bone fragments and bullet were removed. Patient never responded, and died 76 hours postoperatively. Autopsy revealed massive brain damage, and a clean abdomen. The second operation may have been undertaken too early, but this man would probably have died anyhow.

Case 132.—A soldier, age 29, entered ten hours after penetrating wound left parietal skull by 30-caliber bullet. He was unconscious, with a pulse of 60 and B. P. 160/80. Had a very large brain herniation, right spastic hemiplegia, and pupils were markedly contracted. After blood and plasma, operation was undertaken 21 hours after admission, and revealed large bursting type fractures, with marked brain damage. Dura was damaged in an area 16 x 8 cm. The bone chips and bullet were removed, but patient's condition was considered hopeless. In an emergency evacuation 24 hours later he was sent to the rear. Although no word has been received, it is presumed that he died.

Case 137.—A 16-year-old Italian civilian male was semicomatose on admission, with a penetrating wound right parietal skull. He had a very large brain herniation, and a left hemiplegia. Roentgenograms revealed a comminuted fracture left parietal skull, with a group of bone fragments driven deeply to the midline. Pulse and B. P. were good, and after plasma and blood, operation was performed 30 hours after injury. A bone defect, 6 x 8 cm., with a dural defect, 3 x 6 cm., were found. He had a very long tract, all the way to the falx, where the majority of the bone chips were found. On their removal considerable early degeneration was found around them. Despite supportive treatment patient died ten hours postoperatively. Postmortem examination revealed extensive brain damage.

Case 138.—A soldier, age 23, was received two hours after a bombing accident, with multiple severe penetrating wounds, in addition to the scalp wound he had penetrating wound of the face, neck, chest and abdominal walls, both legs and both arms. He had a compound comminuted fracture of the right radius in addition to the one of the right parietal skull. All the wounds were considerably contaminated with clay and dirt. B. P. was zero, pulse was very rapid and thready. Fifteen hundred cubic centimeters of whole blood and 3 units of plasma improved his general condition, so all wounds but that of the skull were attended to, with immobilization for the fractured radius. Twenty-four hours later, after 500 cc. whole blood, craniotomy was started, and a depressed fracture, with a subdural hematoma, was found. Patient failed rapidly, and died as the wound was closed. The second-stage procedure was probably attempted too early, and this is probably one of the cases in which the skull procedure could have "waited" until careful observation for at least another 24 hours.

#### SUMMARY AND CONCLUSIONS

1. Definitive surgery for penetrating head wounds should be undertaken in the forward Evacuation Hospitals, which are the first installation with proper equipment and personnel for the handling of these cases.
2. Emphasis on early surgery for battle wounds applies strongly to cranial wounds, just as it does to other parts of the body.
3. There is a definite group which would not survive a long time-lag. These cases are best operated upon in a forward Evacuation Hospital.
4. The anesthesia of choice is endotracheal ether.
5. The dura must be closed, and neighboring pericranium or fascia is usually adequate. Preserved cadaver grafts have been useful in certain large defects.
6. Lack of dural pulsation indicates the need for subdural investigation, when intact dura is found beneath bone.

7. The importance of the liberal use of blood cannot be overemphasized.
8. The establishment of a Head Ward, with trained personnel, has lowered our mortality.
9. In patients presenting other severe wounds in addition to the penetrating head wounds, it is often best to undertake surgery in stages.
10. It is far more important to remove indriven bone fragments than metallic fragments. However, a greater effort to remove the latter should be made.
11. There is no indication for the routine use of drains in these cases.
12. Tripod incisions should be avoided.
13. The exact relative importance of penicillin and sulfonamides in the treatment of penetrating wounds of the head is still to be established.
14. Thorough, painstaking and rather radical débridement of damaged brain tissue is essential to a lowering of morbidity and mortality.

ADDENDUM: Since the preparation of this paper, 146 additional craniotomies have been undertaken for penetrating head wounds. There have been 12 deaths. It is too early to draw any additional conclusions.

# EXPERIENCES WITH INJURIES AND DISEASES OF BONE IN WORLD WAR II

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AND

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PROGRESS in the treatment of bone injuries and diseases resulting therefrom has been steady ever since World War I, and during the present conflict has accelerated at a rapid pace. During the past 20 years there has been an increasing tendency for this branch of Surgery to be confined to bone specialists and orthopedic surgeons. However, a shortage of trained orthopedists has made it necessary that some of this work again come under the care of the general surgeon, and it is with that care, and from that standpoint, that this communication is concerned.

Ordinarily an Evacuation Hospital would treat only acute bone injuries, but by force of circumstances our hospital for many months has acted as a General Hospital for Chinese troops and has had to supply definitive and final treatment for all types of conditions. Our aim has been to obtain the best results possible by the simplest methods, and in the shortest time.

We have seen a large volume of cases—a certain number of them being recent injuries—but the majority have received primary treatment at some other installation and passed through a second hospital before coming to us. Thus, the number of cases of osteomyelitis constituted a much larger percentage than a complete tabulation of all injuries received in any theater of war would show. While we have had cases of injury to practically every bone in the body—many of them being compounded—we will only discuss the treatment of the more common types.

A word about the condition of our patients is in order. While most of them are young, their general average of health, upon return from the battlefield, is apt to be below par. They tend to be undernourished, anemic, and the majority have chronic malaria and general infestation with worms. We have no direct evidence to show that bones will not heal as quickly in such a patient but we have found that wounds of the soft parts become infected more easily, granulate more slowly, and are much slower to return to normal. A probable deficiency of vitamin C makes operative wounds bleed so freely as to be more than troublesome at times.

As already stated, we have tried to use the simplest methods which will give the best results. In general, we prefer closed to open reductions; skin traction to skeletal traction, and plaster splints and encasements to the complicated metal splints. We have no hesitation in using any of the nonpreferred methods if as good and as rapid results cannot be obtained otherwise. For instance, a badly aligned transverse fracture of the first metatarsal in a colored boy was plated immediately when we were unable to reduce the displacement



by closed methods. Muscle and tissue were found between the ends. We have had to plate seven fractures of the shaft of the femur for the same reason. While we have been fortunate enough to have no infections resulting from our open reductions or use of pins and wires, the fear of such infection is constantly in our mind and we prefer not to subject the patient to that risk.

Most fractures of the clavicle respond to simple treatment—a cruciate splint, holding the shoulders back and leaving the arms free, has, in general, proved satisfactory. They can be returned to duty in three weeks. In three cases where separate slivers of bone threatened to injure the subclavian vessels, these were removed through a small incision. The clavicle is a relatively unessential bone and we have not considered that accurate anatomic reduction was necessary—so have not attempted the wiring operation lately advocated in some clinics. In cases of osteomyelitis the most rapid closure is obtained by removing the whole involved portion. We have seen one case of congenital absence of both clavicles in a soldier who was perfectly able to carry on his duties.

Fractures of the scapula require little treatment beyond strapping and rest of the part. They are much more common in war surgery than in civilian practice. Osteomyelitis may be rather extensive, and in one case required removal of the entire body of the scapula. Fractures of the ribs, where there is no pleural or pulmonary damage, are also simple to care for. Infection may be extensive and tends in some cases to spread rather rapidly. Operation for removal of infected ribs is not simple, and great care must be taken to avoid entering the pleural cavity. This happened in one of our cases, with an eventual fatality.

Fractures of the vertebral bodies are treated by plaster jackets and rest for four months. The rest in the case of our Chinese patients often is highly theoretical, and it is not at all uncommon to find them visiting the nearest bazaar a week or so after their injury. The fact that they seem to recover as rapidly and with no more ill effects than those patients whom we do control, makes us wonder whether this long period of rest is necessary. Fractures of the transverse processes are common and respond quickly to two or three weeks rest either in a light plaster jacket or merely adhesive strapping. This is in marked contrast to most of the cases we have seen in civilian practice—especially compensation cases where the complaint of pain persists for many months.

The “hanging cast” for fractures of the shaft of the humerus has in our hands given excellent results. Even compound fractures respond very well and it is only in fractures of the surgical neck that it is necessary to fix the arm in full abduction, and exert traction to obtain proper realignment of the fragments. Six to eight weeks immobilization in most cases proves sufficient and early treatment with heat and massage helps to restore full motion. In these fractures, as in all fractures, we are much more interested in a good functional result than in the anatomic result. If both results are good, so much the better. Fractures about the elbow, particularly when compounded, may

be especially destructive. Fractures of the olecranon process or the epicondyles should, in general, be treated by open reduction and accurate replacement of the fragment. Early active motion is indicated. When the joint is destroyed, and ankylosis is the unavoidable outcome, an effort is made to have this occur with the arm in about 80 degrees flexion.

A large proportion of the cases of fractures of the bones of the forearm has been due to battle wounds; often with considerable loss of the bone. Many cases of osteomyelitis result which frequently entail further loss of bone. When both bones are equally affected, the quickest result is obtained by resecting the diseased part and wiring the ends together, thus, deliberately shortening the forearm. Surprisingly good function results. In other cases, once the infection has been cleaned up, it is necessary to insert some form of bone graft. Since this is designated an Evacuation Hospital and we, therefore, lack a motor saw, we have used the medullary peg-type of graft, which when accurately inserted and adequately fixed, gives excellent results. Wounds of the hand with damage to the metacarpals and phalanges are very common. A recent article in the Naval Medical Bulletin, by Webster,<sup>1</sup> brings out some interesting methods of treatment. When there is marked infection early amputation of the affected finger or fingers often proves the most conservative procedure in the long run. The loss of two fingers does not preclude the return to duty of the Chinese soldier.

Fractures of the pelvis have been about equally divided between those due to wounds and the simple uncompounded injuries. In only one case has the urethra been torn. These cases were generally treated by placing the patient on a hard-surfaced bed, with Buck's extension on both legs. The sling-type of suspension has not been necessary as a rule. The results have been satisfactory.

As might be expected, we have had relatively few fractures of the neck of the femur. We may have erred on the side of conservatism in not using pins or nails in those cases, yet our results with the use of the Whitman abduction spica have been fairly satisfactory. Most of these cases have been able to return to duty by the end of 18 weeks. Fractures of the shaft of the femur have been mostly of the compounded variety. Several of the simple cases have required plating, as stated earlier. Instead of a spica we have used, in many cases, a three-way splint—first shown to one of us (W.M.W.) by Dr. James M. Hitzrot, of New York City. This consists of a long six-inch-wide plaster splint posteriorly, extending from the tip of the scapula to the end of the toes; a second similar splint applied laterally from the lower ribs to the tip of the lateral malleolus; and a third shorter splint running obliquely across the anterior surface, the proximal end fastened over the anterior superior spine, and the distal end grasping the inner surface of the knee. These splints are easily applied and possess several advantages over a spica: (1) They are much more comfortable. (2) They are easily adjustable—in many cases the patient loses weight and if in a spica there may be some shifting of the fragments. Splints are easily tightened so as to continue to hold the fragments in

good apposition. (3) They are less liable to cause pressure sores and necrosis. With our Chinese patients this is especially important. In one of these cases—although circulation of the toes seemed adequate, and there were no complaints of pressure—when the spica was removed there was found extensive slough of the whole lateral group of muscles of the lower leg. This occurred in a patient with fractures of both femora and one humerus, who was for many days in a very precarious condition, and in a poor state of nutrition, but, nevertheless, we believe it would have been avoided if splints had been used. (4) Two of the splints can be removed so as to apply early massage to the muscles and maintain their tone. One of our operative cases was enabled to return to duty four months after operation by this treatment. Russell traction has proven relatively unsatisfactory in the treatment of these fractures. There has been a lack of sufficient personnel to closely supervise these cases and the Chinese, not understanding what we are attempting to accomplish, are apt to request their friends to remove the weights and traction. In a few cases we have used traction just long enough to align the fragments and then have applied splints.

Fractures of the tibia have, upon occasion, required pins through the os calcis for proper reduction. Compounded wounds, with loss of bone substance and infection, are first treated for their osteomyelitis and as soon as this is cured, are grafted. Here, every effort is made to prevent shortening. Fractures of the tibial plateau running into the joint, with separation, require open fixation. Generally, one or two screws will accomplish the desired result. Early active motion of the joint is indicated though weight-bearing is not allowed for a period of 12 weeks. Infections involving the fibula alone are treated by excision of the entire part involved. All but the lower end of this bone can be removed, with no loss of function.

War wounds of the feet are apt to be particularly disabling. With even a comparatively good result, if any pain remains the soldier is no longer fit for duty. Therefore, in these cases we can afford to take a longer time, be conservative in our treatment, and try and cut the resulting disability and deformity to a minimum.

It is in our treatment of osteomyelitis that perhaps the greatest advances have been made. With the advent of the sulphonamides and penicillin—our experience with the latter has as yet been somewhat limited due to scarcity of the drug—we are able to operate earlier; operate more radically; and, thereby, sooner effect a cure. As has been often stated, these drugs are no substitute for adequate surgery but they are of great assistance in limiting and clearing-up infections. We see none of the terrific systemic reactions which formerly so frequently followed operations for osteomyelitis. As a rule, by six weeks after the original injury we are able to determine whether or not there is infection of the bone. Open unhealed sinuses, extrusion of bone fragments, and long-continued drainage are all indications of such infection. Repeated roentgenograms, for comparative purposes, will help to show if the process is progressing. It must be remembered however that roentgenograms seldom

## INJURIES AND DISEASES OF BONE

show the full extent of involved bone, and operation generally reveals a much further-advanced process than was suspected. Our usual procedure is to start sulfathiazole treatment about four days before the contemplated operation and continue it for six or seven days thereafter. The operation must be thorough and complete and all infected bone and dead bone fragments removed. Frequently small shell fragments are found and removed at the same time. The bone is saucerized; lightly packed with vaselined gauze; and an encasement applied. Depending upon the amount of discharge this is not changed

TABLE I

SUMMARY OF BONES INVOLVED, DEGREE OF INJURY, PERIODS OF IMMOBILIZATION AND HOSPITALIZATION, AND INSTANCES OF OSTEOMYELITIS

Bone Involved:	S—Simple C—Compound	Average Time of Immobilization	Average Time of Hospitalization	No. of Cases of Osteo.	% of Osteo.
Humerus.....	S 23 C 108	5 weeks 6 weeks	8 weeks 11 weeks	22	20.3
Radius.....	S 26 C 83	4 weeks 6 weeks	6 weeks 9 weeks	16	19.3
Ulna.....	S 20 C 102	4 weeks 7 weeks	8 weeks 11 weeks	19	18.6
Femur.....	S 16 C 44	8 weeks 9 weeks	11 weeks 14 weeks	18	18.1
Tibia.....	S 39 C 88	6 weeks 8 weeks	10 weeks 12 weeks	32	36.4
Fibula.....	S 25 C 61	6 weeks 6 weeks	9 weeks 11 weeks	19	31.1
Scapula.....	S 4 C 27	1 week 4 weeks	4 weeks 7 weeks	3	11.1
Clavicle.....	S 9 C 17	3 weeks 3 weeks	5 weeks 8 weeks	1	5.8
Ribs.....	S 22 C 24	1 week 2 weeks	3 weeks 7 weeks	4	16.9
Phalanges.....	S 9 C 50	2 weeks 6 weeks	4 weeks 6 weeks	11	22.0
Metacarpals.....	S 4 C 69	5 weeks 5 weeks	5 weeks 8 weeks	6	8.6
Metatarsals.....	S 10 C 32	3 weeks 5 weeks	7 weeks 8 weeks	5	15.6
Patella.....	S 3 C 9	1 week 6 weeks	6 weeks 10 weeks	1	11.1
Os calcis.....	S 2 C 14	4 weeks 11 weeks	12 weeks 15 weeks	6	42.8

for from three to six weeks. If the operation has been adequately performed, at this time a clean granulating wound is found. If there has been extensive loss of skin, a split-thickness graft is placed on the granulations as soon as they are level with the surface. In a few cases where there has been extensive loss and the bone ends show only slight infection, this is cleaned out and an immediate bone graft is introduced. In these carefully selected cases this has worked satisfactorily and much time has been saved. How many of these cases will have recurrences and flare-ups of their bone infection, only time can tell. In still other cases when the infection is limited, we have attempted primary closure of the wound. The results in these cases have been excellent, but great care must be used in their selection. In some instances with considerable bone loss a muscle graft has been used to fill in the defect. This was recently done in an extensive involvement of the sacrum, a section of the

gluteus maximus being swung into the cavity left after curettement, with resultant closure by primary union. Since starting this method of treatment, an article by Key<sup>2</sup> has been called to our attention. His experience and results have encouraged us to further extend our efforts in this direction, and we now have a series of over 20 completed cases so treated, with primary union in over 80 per cent. These will be reported in detail by some of our colleagues in the near future.

To date, we have treated 976 patients, with 1,108 fractures. Of these, 260 were simple and 848 compounded. Six per cent of our patients were American and 94 per cent Chinese. We have had 175 cases of osteomyelitis. Two hundred twenty-five patients are still under treatment in the hospital. Of the 751 discharged, 628, or 83 per cent, were able to return to full duty; 50, or 6 per cent, were sent to other installations as permanently unfit for duty; 18, or 2 per cent, were transferred to another hospital for further treatment; 52 patients, or 7 per cent, went absent without leave—a fair presumption that they were well on their way to recovery. There have been three deaths in our series. A short outline of the more important bones involved with periods of immobilization and hospitalization is appended (Table I). The cases not included consist of fractures of the skull, the facial bones, sternum, *etc.*

#### SUMMARY

1. A brief review of our methods of treatment of fractures in a war zone is presented. These are all directed toward the earliest possible return of the soldier to full duty.

2. A three-way splint used for fractures of the shaft of the femur is described.

3. New advances in the treatment of osteomyelitis are described. These are presented as a suggestion for further trial and experiment and not as a settled policy.

#### REFERENCES

- <sup>1</sup> Webster, George V.; Lieut, M. C., U. S. N. R.: Simple Fractures of the Metacarpal Diaphyses. Naval Medical Bulletin, 42, No. 3, 623-646, 1944.
- <sup>2</sup> Key, J. Albert: Sulphonamides in the Treatment of Chronic Osteomyelitis. Jour. Bone and Joint Surg., 26, 63-70, January, 1944.

## EXPERIENCES WITH SYMPATHECTOMY IN PERIPHERAL LESIONS

LT. COL. JAMES A. KIRTLEY, JR., M.C., A.U.S.

VARIOUS LESIONS manifesting vasospasm of the extremities have been encountered on the Surgical Service of a General Hospital in a Theater of Operations. It has seemed desirable to resect portions of the thoracolumbar sympathetic chain in certain of these lesions. The cases under study cover a period from March, 1944, to September, 1944. It is recognized that the period of observation following operation is entirely too short to draw any positive conclusions, but it is hoped that discussion of the operative indications and early postoperative results will be of interest.

During the past six months, 41 lumbar ganglionectomies have been performed upon 36 patients by members of the surgical staff. An effort has been made to familiarize the younger men on both general surgery and orthopedic surgery with the indications and operative technic. There have been no deaths or complications except for two wound infections, which will be discussed later. Two patients had lumbar ganglionectomies in forward hospitals before admission to our hospital, and they are included in Table II.

The 38 patients having 43 sympathectomies have been divided into five groups for study and discussion. With few exceptions, they all presented evidence of peripheral vasospasm which could be abolished temporarily by preliminary paravertebral injection of procaine hydrochloride.

### GROUP I—SYMPATHECTOMY FOR SEQUELAE OF "TRENCH FEET"

There were 23 operations (17 patients) in this group, which is the largest. No attempt will be made to discuss the early pathologic changes which follow exposure of the extremities to dampness and cold. The author had the opportunity of seeing the patients studied by Angelucci and Berson,<sup>1</sup> and agrees, in general, with their conclusions. They found that repeated sympathetic blocks exerted little if any effect on early cases but were beneficial in late cases in which vasospasm was pronounced. As shown in Table I, the interval between exposure and sympathectomy varied between two months and seven months. All patients were originally hospitalized for a time, and many were then returned to either full or limited duty, but because of pain on walking, swelling or persistent vasoconstriction had to be rehospitalized. These patients exhibited the following physical signs in varying degrees:

- (a) Cold, clammy feet with or without swelling.
- (b) Cyanosis, especially when the feet were dependent.
- (c) Diminished or absent peripheral pulsations.
- (d) Gangrene of toes or ulceration of skin (nine patients).
- (e) Trophic changes of skin and nails.
- (f) Excessive sweating from pearly white, papular lesions on feet, with or without superimposed infection.
- (g) Tenderness on palpation or pain on weight bearing.

TABLE I  
LUMBAR SYMPATHECTOMY FOR SEQUELAE OF TRENCH FEET

Case No.	Age	Preoperative Findings	Interval Between Injury and Operation	Side Operated	Operative Complications	Operative Results	Remarks
1	25	Left foot cold, cyanotic. Absent post tibial. Marked vasospasm.	5 months	Left	None	Excellent	Patient previously hospitalized twice for trench feet. Preoperative lumbar block showed marked vasospasm. Patient returned to full duty.
8	25	Foot icy, cyanotic. Absent pulses, also compound frac. great toe.	2 months	Left	Aggravation of old traumatic arthritis	Improved	Patient had pain in left lumbar region postoperatively, which was probably due to traumatic arthritis of spine. Because of bouts of fever, the operative wound reopened. 30 days postoperative but no evidence of infection.
10	35	Foot cold, clammy and cyanotic, with absent pulsations. Vasospasm marked.	2.5 months	Right	None	Improved	Postoperatively, the foot was hot and dry, and the swelling decreased, but the pre-existing pain on walking continued.
12	19	Foot cold, wet & skin shiny and atrophic.	2.5 months	Right	None	Excellent	A small area of gangrene, skin on the great toe sloughed, but the ulceration healed following operation. Patient returned to duty.
13	22	Feet cold, very dusky, wet, painful & swollen. Left more than right.	2 months	Left	None	Improved	Patient also had marked vasospasm of fingers following exposure to cold. Pain persisted after sympathectomy.
14	21	Dry gangrene—2 toes. Foot cold clammy and cyanotic.	4.5 months	Left	None	Improved	Previous hospitalization for trench feet—2 months before this injury. Pain in balls of both feet continued—the vasospasm was relieved.
15	26	Gangrene — 2 toes. Foot cool, skin shiny and atrophic.	2.5 months	Left	None	Improved	This patient had gangrene of toes on both feet. The left foot was cooler than the right. Healing occurred more rapidly on the left following operation. Foot hot and dry.
16	25	Feet cold, clammy, cyanotic and tender on palpation.	2.5 months	Left	None	Improved	Pain on walking persisted in both feet though the patient stated that his "left foot felt much better than the right one."
17	19	Hyperhidrosis, severe with whitish lesions on foot, which dripped sweat.	5.5 months	Left	None	Excellent	Following a period of hospitalization for "acute trench feet" the patient was sent to a replacement depot. Excessive sweating kept skin macerated, and he was unable to do duty. He was returned to duty following bilateral sympathectomy.
18	19	As above. Maceration of both feet.	4 months	Left	None	Excellent	To duty following bilateral sympathectomy.
19	20	Pearly white lesions on foot, which dripped sweat.	5 months	Left	None	Left foot 6° F. warmer than right	Hospitalized for 5 months before for trench feet. No duty since because of pain and sweating. Duty one month postoperatively.
20	35	Hyperhidrosis, with maceration.	7 months	Right	None	Excellent. Rt. foot 5° F. warmer than left.	Two episodes of "acute trench feet." Replacement depot for 5 months. Could not do duty because of sweating and maceration. Sent to duty following operation.
21	20	Hyperhidrosis, with maceration, pain and swelling.	5.5 months	Left	None	Improved	Left foot 4° to 5° F. warmer than right after operation. Skin lesions healed. Pain on walking persisted. Previously hospitalized for 8 weeks.

# SYMPATHECTOMY FOR VASOSPASM

TABLE I (Continued)

## LUMBAR SYMPATHECTOMY FOR SEQUELAE OF TRENCH FEET

Case No.	Age	Preoperative Findings	Interval Between Injury and Operation	Side Operated	Operative Complications	Operative Results	Remarks
22	20	Hyperhidrosis. Severe burning. Pearly - white lesions.	3.5 months	Left	None	Improved	Left foot 4° F. warmer. Lesions healed promptly, but subjective pain on walking about equal in each foot.
23	28	As above.	6 months	Left	None	Improved	3° to 4° F. warmer on left. Pain and slight swelling of both feet persist.
24	21	Bromidrosis, sev. maceration, sev. cold cyanotic feet.	5.5 months	Left	None	Excellent	Exposure in Nov. & Dec. 1943 (Italy). Conservative treatment for 3 months with astringent solutions & change of socks every few hours did not prevent maceration or fetid odor.
25	19	See Case 18.	4 months	Right	None	Excellent	13-day interval between operations.
26	19	See Case 17.	6 months	Right	None	Excellent	13-day interval between operations.
28	22	Gangrene skin on dorsum of foot. Cold, wet and cyanotic.	3.5 months	Right	None	No improvement	There was doubt as to whether sympathectomy was accomplished at operation. Foot was warm and dry for a week but later starch-iodine test showed sweating and temp. was equal to, or less, than normal foot.
29	20	Hyperhidrosis, sev. Multiple ulcers due to maceration.	4 months	Left	None	Excellent	Patient had hyperhidrosis as truck driver in civilian life, and had to change socks several times a day. Has had repeated ulcers despite medical treatment.
30	20	Same patient as Case 29.	4 months	Right	None	Excellent	10-day interval between operations. Patient returned to full duty one month later.
32	21	Same patient as Case 24.	6 months	Right	None	Excellent	Full duty. Both feet warm, dry and lesions healed.
34	20	Hyperhidrosis, sev. Dermatitis, secondary, sev. Absent D. P. pulse.	6 months	Left	None	Excellent	Patient treated for 2.5 months in bed, with ointments, penicillin, wet dressing, etc., without benefit. Sympathectomy request by Med. Service. Lesions promptly healed. Temp. right foot 94° F. left 96.8° F. Duty one month postoperative.

Total—23 operations in this group.

It is difficult to evaluate the results obtained because of the relatively short period of observation after operation. Approximately 50 per cent were returned to duty within a month after sympathectomy. The tactical situation in the theater limited the period of hospitalization and some were returned to the Zone of Interior and thence to duty. Other patients with loss of toes were discharged from the service. In general, lumbar ganglionectomy was most effective in patients exhibiting severe hyperhidrosis, with maceration and secondary infection. Most of these men had not performed any duty for several months and had been repeatedly hospitalized despite strict foot hygiene and frequent changes of socks. The results were less satisfactory in patients who had painful feet, with or without swelling. Following operation the feet became hot, dry and flushed, with full veins and strong arterial pulsations but pain on weight bearing continued. Later observations will indicate



whether pain in the sympathectomized foot will continue as long as on the unoperated side.

The following case history is typical of the late sequelae of trench feet:

**Case 18.**—T. S. H., male, white, age 19, was admitted to this hospital, in May, 1944, from a replacement depot. Patient had had 18 months of infantry duty with a minimal amount of foot trouble. Feet were wet and cold from January 12, 1944, to February 12, 1944. Patient noted burning on February 9, 1944, and was admitted to a hospital February 13, 1944. Both feet were swollen on admission and remained swollen for a month, though graded activity was begun in three weeks. In March, 1944, the patient was sent to a replacement pool and began a program of light physical training. Feet began to sweat profusely, the skin became tender and macerated and burning pain recurred. On admission here, general examination was normal. Hands were dry and there was little evidence of psychosomatic disturbance. Feet were cold and pale but quite wet with whitish, raised patches across plantar aspect of right foot. Arterial pulsations were present but diminished (B. P. 130/80). Paravertebral block resulted in marked flushing and dryness of feet:

The second and third lumbar sympathetic ganglia were removed on the left side and, 13 days later, on the right side. The lesions disappeared within a week and the patient became ambulatory. Starch-iodine tests showed no sweating below mid thigh levels. Temperatures taken with clinical thermometers between the second and third toes showed the left foot to be 4° F.—6° F. warmer than the right following the first operation. The patient was discharged to duty four weeks after the second operation.

#### GROUP II—ARTERIAL INJURIES

There were ten patients admitted following shell fragment wounds, in which major arteries were injured (Table II). As this series is too small to draw definite conclusions, each case will be elaborated upon in addition to basic data given in Table II.

**Case 2.**—On admission, six days after ligation of vessels in the femoral triangle, there was swelling of the thigh and leg with purplish, splotchy areas on the lower half of the leg and foot but no clear line of demarcation. There was early gangrene of the right second toe, with greenish (yeast) discoloration at the base of the toe on the dorsum of the foot. Sympathectomy was performed in the hopes that later amputation might be undertaken below the knee. The thigh and upper half of the leg became warmer but the foot remained unchanged except that the greenish discoloration had extended well above the ankle in 24 hours. The day following sympathectomy, circular incision through the middle portion of the leg revealed the calf muscles to be pale and friable, with loss of contractility and all veins to be thrombosed. A knee joint disarticulation was then done, and the patient made an uneventful recovery. Microscopic sections from both anterior and posterior muscle groups showed early necrosis of muscle fibers, with shrinking and separation from the sarcolemma. Lumbar blocks, or earlier sympathectomy, might have changed the outcome. Elevation of the leg prior to admission did not increase the chances of limb survival.

Cases 4, 33, 36 and 37 may be considered together, as they all had ligation of the femoral artery, with survival of the extremity. Each had from one to three lumbar blocks in the first few days. The involved extremities were all much colder, and intermittent claudication occurred on walking. All had lumbar blocks, which showed increased warmth in the extremity prior to sympathectomy, so that vasospasm was present to some degree. Case 37 had claudication after walking 200 yards on level grounds, and three weeks after sympathectomy the patient walked a mile without any cramping.

## SYMPATHECTOMY FOR VASOSPASM

TABLE II

## LUMBAR SYMPATHECTOMY IN ARTERIAL INJURIES

Case No.	Age	Preoperative Findings	Interval between Injury and Sympathectomy	Side Operated	Operative Complications	Operative Result	Remarks
2	31	Femoral ligated P/3 — D/2 leg cold—Gangrene 2nd toe.	6 days	Right	None	Probably unchanged	Patient had had no lumbar blocks and extremity had been elevated on 4 pillows prior to admission.
4	27	Ligation femoral P/3. Absent pulsations — cold feet & anginal crisis.	34 days	Left	Mild infection of wound	Marked increase in warmth of leg	The shell fragment wound was infected on admission, and the infection of the operative wound was probably due to retroperitoneal lymphangitis.
7	34	Com'p fracture tibia & fibula. Early gangrene, with icy foot.	13 days	Right	None	Improved	Foot became warmer following operation but supramalleolar amputation was done ten (10) days later because of gangrene present on admission.
27	47	Ligation popliteal vessels. Cold discolored foot.	4 days	Right	None	Little change	Gas gangrene developed, necessitating amputation at knee 48 hours later. Extensive thrombosis of leg vessels found on dissection of specimen.
33	22	Ligation femoral D/3 — Cool, pulseless foot.	30 days	Left	None	Excellent	Left foot was 2° F. warmer than normal side, and patient's walking range greatly increased.
36	21	Ligation of femoral P/3—Cool foot, intermittent claudication.	71 days	Left	Infection of wound	Excellent	Can walk much farther before cramping occurs. Infection probably due to disturbance of retroperitoneal lymphangitis which followed original shell fragment wound.
37	21	Ligation femoral N/3. Claudication after 200 yards.	86 days	Left	None	Excellent	Left foot 2° F. to 4° F. warmer than normal foot. Can walk without claudication.
40	28	Ligation popliteal vessels—icy foot, gangrene big toe. Com'p frac. fibula.	5 days	Left	None	Little change in temp. of foot	Amputation, 3 days later, lower third leg because of fever, preexisting gangrene and necrosis of gastrocnemius and soleus. Sympathectomy probably permitted amputation at a lower level.
41	19	Ligation femoral P/3. 4 "lumbar blocks." Cold, pulseless foot.	2 days	Left	None	Excellent	Foot suddenly became warm about 40 hours after operation, and remained as warm as normal one.
42	20	Ligation popliteal. Lumbar block 1. Com'p fracture head of fibula.	1 day	Left	None	Fair	Gangrene of tips of two toes remained unchanged and foot was warm. Lower leg amp. was done 72 days later because of chronic sepsis from tarsal and ankle wound and foot drop.

Total: Ten operations.

Infection in the extraperitoneal incision developed in two of this group, and were the only postoperative complications in the series of 43 operations. These patients all had large thigh wounds and it was felt that disturbance of the retroperitoneal lymphatics at the time of sympathectomy was responsible for the postoperative infection. Both wounds healed after a short period of drainage, without disruption or subsequent herniation.

Case 7 is the only one in the group in which there is no mention of arterial injury. This patient had fractures of both bones of the lower third of the leg, with a cold foot. He had daily paravertebral blocks before ad-

mission, but the leg was kept elevated on "four blankets." There was early mummification of the toes, with absent pulsations on admission. Amputation was required ten days later because of gangrene on the plantar surface. Dissection of the specimen showed all vessels to be thrombosed in the foot.

Cases 27, 40 and 42 all had ligation of the popliteal vessels, and ultimately all required amputation, though for different reasons. Case 27 had had an extensive posterior fasciotomy of the leg and lower half of the thigh and ligation of the popliteal vessels two days prior to admission for perforating wound of the lower thigh and leg. On admission, the patient was found to have a total plasma protein value of 5.6, hematocrit of 22, and hemoglobin of 7.6 Gm. Penicillin 25,000 units every three hours was begun, and he received 1,000 cc. of whole blood on the first and third day after admission here. The foot was cold, bluish and pulseless, but the lower leg became warmer following daily paravertebral blocks. On the fourth day after injury sympathectomy was performed. Forty-eight hours later there was a sharp rise in temperature to 103.8° F., and examination of the leg at this time showed the posterior muscles to be almost purplish in color with crepitation in the muscle bundles and fascial planes. A low thigh amputation was performed because of the extensive necrosis and the clinical diagnosis of gas gangrene. Examination of the specimen showed the vessels to be thrombosed.

Case 40 had two lumbar blocks before admission, and gangrene of skin of 5th toe. Immediately following sympathectomy the original leg wounds were extended and nonviable portions of anterior tibial and gastrocnemius muscles were excised. Three days later a midleg amputation was performed. It was felt that sympathectomy permitted a below the knee amputation. Case 42 had ligation of the popliteal vessels 24 hours after being wounded, and eight hours later had sympathectomy. Gangrene of the tips of two toes developed, but the foot was warm even though there were no peripheral pulsations. Patient had several perforating wounds of the foot and ankle which continued to drain pus. He also had foot drop due to peroneal nerve injury, and marked pes cavus. Amputation through the lower leg was performed 73 days after injury because of the chronic sepsis of tarsal bones and foot drop. In Case 41 the common femoral vessels were ligated and divided just below Poupart's ligament, and lumbar blocks given twice daily. The foot and leg remained cold, however, and the 2nd, 3rd and 4th lumbar ganglia were resected 48 hours later in a Forward Hospital. There was little change for 48 hours, at which time the foot became as warm as its mate and remained so.

In three of the five patients requiring amputation, sympathectomy was performed at too late a date to be effective—6, 13 and 5 days, respectively. It is believed that following damage to the main artery of an extremity immediate "lumbar blocks" should be done, and if there is any question as to viability of the extremity, early sympathectomy should be performed.

The results of sympathectomy in the "late" cases, with claudication and cold, wet feet, have been most satisfactory.

# SYMPATHECTOMY FOR VASOSPASM

## GROUP III—POSTTRAUMATIC VASOSPASM

There were six patients who had marked posttraumatic vasospasm of an extremity, with edema. Five had shell fragment wounds, and the other had had extensive second-degree burns. This patient, and one other, also had had thrombophlebitis (Table III). The early results in all six patients

TABLE III  
SYMPATHECTOMY IN POSTTRAUMATIC VASOSPASTIC LESIONS

Case No.	Age	Preoperative Findings	Interval Between Injury and Operation	Side Operated	Operative Complications	Operative Results	Remarks
6	28	Shell fragment wds. of rt. thigh and leg. Foot cold, cyanotic, with pulsations.	1.5 months	Right	None	Improved	Original operative note stated "that the posttibial artery was in spasm." No pulsations were felt except after lumbar blocks. Patient had 7 blocks in all. Marked improvement following ganglionectomy.
11	35	Com'p fractures of fibula & 4th & 5th toes. Foot cold, cyanotic & swollen.	3 months	Left	None	Improved	Patient had been in foxhole for 5 days (Jan. '44) with wet, cold feet prior to being wounded. Marked decrease in pain and swelling postoperatively. Foot warm and flushed and 2.4° F. warmer than right 1 month postoperatively.
35	30	Com'p frac. 2nd metatarsal. Foot cold, dusky & wet.	2.5 months	Left	None	Excellent	Pulsations absent before operation, very strong afterwards. Patient had had no improvement with physiotherapy. Left foot 4° to 5° F. warmer than right.
38	26	2nd-degree burns right leg. Recurrent episodes of swelling. Foot cold and wet.	20 months	Right	None	Improved	Patient thought to have recurrent thrombophlebitis, with chronic edema and vasospasm of foot following gasoline burn. Marked decrease in edema and increase in temp. of foot after ganglionectomy. Final result uncertain.
39	26	Perf. wound mid thigh. Thrombophlebitis. Cool, dusky foot.	3.5 months	Left	None	Improved	Preoperative lumbar blocks showed large element of vasospasm which may have resulted from the perforating thigh wounds instead of following the thrombophlebitis. Definite improvement after sympathectomy.
43	21	Perforating wound foot. Frac. 1st metatarsal. Foot very cold, cyanotic, swollen, painful.	3 months	Right	None	Improved	Foot warm, flushed and dry. Pain and swelling much less. Final result uncertain

have been good. The edema definitely decreased in each instance and the foot became warm and dry instead of cold, cyanotic and wet.

## GROUP IV—OBLITERATIVE VASCULAR DISEASE

There was one patient, a male, age 28, who was diagnosed as having early, obliterative vascular disease (Table IV). While training in Ireland this patient took pride in keeping up with his company on forced marches but near the close of the Tunisian campaign he began to have cramps in the calves of his legs after a mile or so. Examination revealed B. P. 150/80 on

repeated checks but no palpable sclerosis. The dorsalis pedis artery on the right was never palpable except after a block. The feet were cool and moist but following paravertebral blocks became quite hot and dry. Following staged operations patient was discharged to lighter duty. It has been pointed out by many observers that there is usually a certain amount of vasospasm along with the organic obstruction and that it is important to remove this factor.

TABLE IV  
SYMPATHECTOMY IN OBLITERATIVE VASCULAR DISEASE

Case No.	Age	Preoperative Findings	Duration of Symptoms	Side Operated	Operative Complications	Operative Results	Remarks
3	28	Early Buerger's disease. Absent. D.P. pulsation, foot cool	14 months	Right	None	Excellent	B.P. 150/80. Retinal vessels normal. Arteries not palpably sclerosed. After training in Ireland patient began to have claudication on marches in Tunisia. Dampness and cold made condition worse. Preoperative blocks showed marked increase in temperature and arterial pulsations, flushing and filling of veins. Patient sent to limited duty.
5	28	Same case as above.	14 months	Left	None	Excellent	14-day interval between operations

#### GROUP V—CAUSALGIA

There were two patients subjected to sympathectomy for severe causalgia (Table V). One of them obtained marked relief of the burning pain (Case 9), and there was moderate improvement in the other patient. The first patient

TABLE V  
SYMPATHECTOMY IN CAUSALGIA OF THE LOWER EXTREMITY

Case No.	Age	Preoperative Findings	Duration of Symptoms	Side Operated	Operative Complications	Operative Results	Remarks
9	35	Penetrating wound right buttock. Severe burning pain in foot. Trophic changes.	2.5 months	Right	None	Excellent	Sciatic neurolysis gave no relief from burning and hyperesthesia. Repeated paravertebral blocks gave temporary relief. Marked relief following pre-ganglionic sympathectomy.
31	36	Penetrating wound lower leg. Severe pain in ball of foot. Foot cold and swollen.	1.5 months	Left	None	Improved	Marked decrease in swelling but little improvement in pain. Patient has old hallux valgus and some metatarsalgia of that foot. Foot warm and dry.

received a penetrating wound of the right buttock January 26, 1944. The wound was not débrided, and patient was admitted to this hospital five days later with a one-centimeter wound of the superior medial quadrant. There was hypesthesia of the plantar surface of the foot and severe burning pain in the foot which was made worse by slight weight bearing. On March 16, 1944, the sciatic nerve was explored from the sciatic notch to below the inferior border of the gluteus maximus. The nerve was not lacerated or involved

## SYMPATHECTOMY FOR VASOSPASM

in scar tissue. The pain and sensation of the foot "being afire" continued. Paravertebral blocks gave immediate relief for six to eight hours. Following sympathectomy the patient had only "slight burning in the instep."

The second patient had a cold, swollen, painful foot following a penetrating wound of the lower leg. He complained of burning pain in the ball of the foot. The edema and burning were both improved and the patient was able to discard his crutches. Considering the large number of extremity wounds encountered there have been surprisingly few instances of causalgia.

### EXTRAPERITONEAL LUMBAR SYMPATHECTOMY

All operations were performed through muscle-splitting extraperitoneal incisions. The absence of a tilting table and movable kidney rest lead us to use the anterior incision advocated by Pearl<sup>2</sup> in 1936, rather than the lumbar approach described by White and Smithwick,<sup>3</sup> which we used in our first 14 cases. Spinal anesthesia has been used in the majority of the operations.

In all except a few instances, preganglionic sympathectomy limited to the second and third lumbar ganglia was done, as suggested by White and Smithwick.<sup>3</sup> In the few exceptions, the fourth lumbar ganglia was also removed. The position of the sympathetic trunk was found to be quite constant and could usually be felt with the finger and, thus, more readily isolated. Considerable variation in the size of the trunk and ganglia was encountered. Generally, large ganglia were found to have small trunks. The number and direction of the rami made identification of individual ganglia fairly accurate. Fusion of the second and third lumbar ganglia was found in one instance. In the limited period of observation after operation, we have repeatedly found the denervated limb to be warmer and completely free of sweating four to six weeks later, as determined by the starch-iodine test. Sweating was absent from the midthigh level downward. Rough temperature comparisons were made by placing clinical thermometers between the second and third toes of each foot for five minutes. Further experience may indicate that the fourth lumbar ganglia should be excised in addition to the second and third.

Patients are allowed out of bed within a week, and no complications were noted except in the two infections mentioned earlier. When both extremities were denervated the second operation was performed about ten days after the first.

### CONCLUSIONS

1. Severe hyperhidrosis is a late sequelae of many cases of trench feet. Maceration of the skin and secondary infection may continue for long periods despite careful treatment. Preganglionic sympathectomy has given excellent results in several such cases. Marked vasospasm, with minimal sweating and gangrene, with ulceration, may follow trench feet, and both conditions benefited by sympathectomy. These patients should be carefully selected for operation after a long period of preoperative study. Continued pain following trench feet is not likely to be relieved by operation.

2. Early sympathectomy seems indicated in traumatic injuries to the major arteries of an extremity, especially the popliteal artery. It may be limb-saving in some instances, and frequently will permit amputation at a lower level. It is of marked benefit to those patients with intermittent claudication in the involved leg following arterial ligation and should be performed at an early date before fibrosis and trophic changes occur.

3. Marked vasospasm following injury to the leg or foot, demonstrated by paravertebral blocks, will be improved by sympathectomy. The edema does not always disappear following operation but with the increased use of the foot it is always less than before. Our experiences with denervation for causalgia are too limited for comment, but relief was obtained in two patients.

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# RESURFACING OF DORSUM OF THE HAND FOLLOWING BURNS

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THE PURPOSE of this paper is to describe a technic for resurfacing the dorsum of the hand following injury to the original skin by burns. The method as originally devised has been very little altered, and has been applied to a very large series of cases in both civilian life and in the Services.

In one series of simultaneously incurred burns alone, the dorsi of 37 hands were grafted. This latter group was from the Knights of Columbus fire in St. John's, Newfoundland. Only three hands had less than a 100 per cent take, in spite of the fact that the majority of the recipient areas were contaminated, granulating surfaces.

Depending upon the depth of skin destruction, the hands present a lesion of one of the following varieties:

(a) A surface covered with easily traumatized scar epithelium, or patches of scar epithelium with intervening areas of more or less normal skin (Fig. 1).

(b) A surface covered with "burn keloid" (Fig. 2). By this is meant a lesion which follows burns, particularly deep second-degree burns. This comprises a thin epidermis which overlies a thick fibrous tissue layer consisting mainly of coarse, collagenous bundles. In this layer, epithelial elements, particularly of sebaceous and sudoriferous glands, are encapsulated (Figs. 3 and 4).

(c) Large granulating areas (Fig. 5).

(d) Large granulating areas with exposed tendons and open joints (Fig. 6).

The aims of the resurfacing procedure in all these types of cases are the same, namely, to restore the hand as completely as possible to its original functional activity; to provide a resilient surface which will withstand the ordinary trauma to which the hand is normally subjected; and to furnish a good cosmetic result.

The functional activities most adversely affected following this type of injury are flexion of the wrist, metacarpophalangeal and interphalangeal joints, and abduction of the fingers and thumb. This loss of flexion is due to superficial scar contracture and structural joint changes. The loss of abduction is due principally to interdigital webbing. It should be appreciated that even in superficial burns the structural joint changes are more serious as a cause of limitation of motion, particularly of the metacarpophalangeal and interphalangeal joints, than superficial scar contracture. This is because these joints are so close to the skin surface that any severe inflammatory process, such as that concomitant with burns, affects also the joint struc-



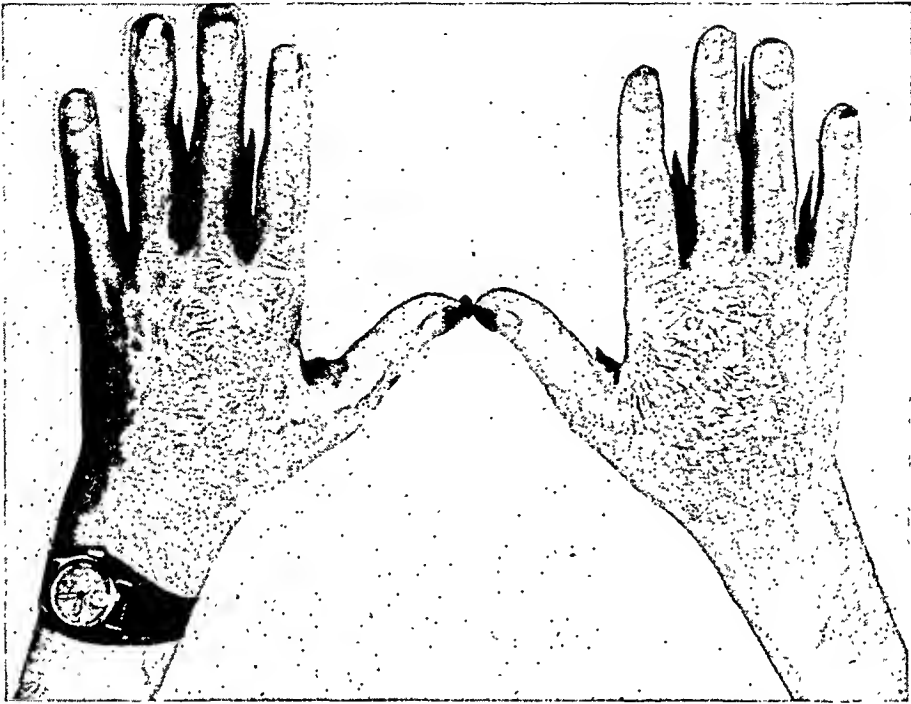


FIG. 1.—Surface covered with easily traumatized scar epithelium.



FIG. 2.—Burn keloid.

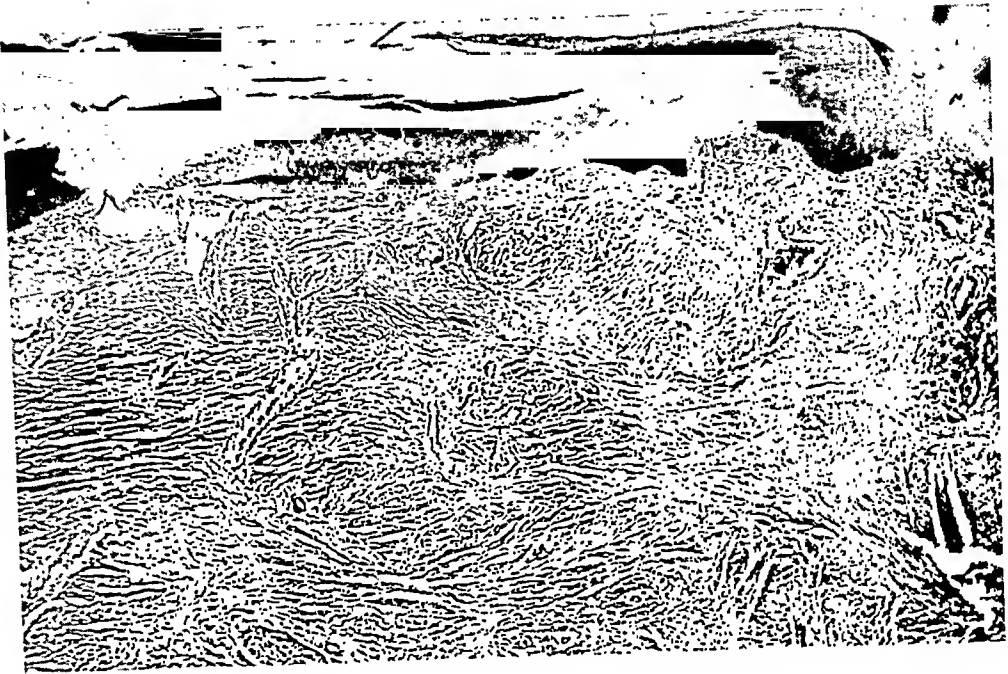


FIG. 3.—“Burn keloid” photomicrograph showing encapsulated groups of sebaceous and sudoriferous glands.



FIG. 4.—“Burn keloid” photomicrograph (high power).

tures. In deep burns the tendons and joint capsules may be exposed after sloughing of the skin or they may even be destroyed so that the joints are open. In some cases, however, the stiffness is due simply to *prolonged* fixation. This does not take place, in the opinion of the writers, with fixation of the fingers for comparatively short periods (*i. e.*, two or three weeks) in cases where the joint structures are not destroyed. It is considered that immobilization in the early stages of the acute lesion is beneficial.

By reason of tendon and joint capsule destruction, extensive joint stiffness and occasionally bony ankylosis result unless resurfacing is performed quickly followed by tendon grafting to restore the motor power to the joints.



FIG. 5.—Granulating surface.

The three aims of any resurfacing procedures can, for the most part, be accomplished by the use of free grafts of .016 or .020 inches in thickness. These grafts will always give an excellent wearing surface and a good cosmetic result. In most cases, this type of graft will also satisfactorily restore the hand to good functional activity. Only occasionally will the use of pedicle grafts be necessary.

The preoperative preparation and the operative technic vary, depending upon the type of surface presenting for repair. When there is no open wound (*i. e.*, when the surface is covered with "scar epithelium" or "burn keloid"), the preoperative preparation is essentially that of any clean surgical procedure. When a granulating surface is present, it is dressed with electrolytic hypochlorite. One part of this solution to 20 parts of water consti-

## RESURFACING DORSUM OF THE HAND

tutes an isotonic solution. An hypertonic solution (1:8-1:12) is customarily employed. In this strength, for a relatively short period (three to four days), the precautionary measure of protecting the surrounding skin with vaseline is unnecessary. Moreover, it is unnecessary, and indeed inadvisable, to change this solution to saline on the last preoperative day, since it is in no way inimical to the take of the graft. The frequency with which these dressings are changed depends upon the amount of discharge or slough. They should, however, always be kept moist. In open wounds, where there



FIG. 6.—Granulating surface with exposed tendons and open joints.

is concern about the cleanliness of the granulating surface, the patient is put on full therapeutic doses of sulfathiazole two days preoperatively as a prophylactic measure. This is to ensure an effective blood level at the time of the operation. This chemotherapy is continued for 72 hours postoperatively. If vomiting is present during the immediate postoperative period, the blood level is maintained by the administration of sodium sulfathiazole intravenously.

The operation is performed under general anesthesia, with the patient lying in the prone position. Since the majority of these lesions are bilateral, two operating teams work simultaneously (Fig. 7). The evening before operation the finger nails are cut, cleaned and scrubbed meticulously. At operation, in clean cases, the hand is scrubbed with soap and water,

using a soft brush. This is sluiced-off with saline, dried, and followed with the customary antiseptic preparation. In cases presenting granulating areas, the skin surrounding the granulations is prepared as above, but the granulating area itself is merely sluiced-off with physiologic saline.

Just prior to draping the patient, a pneumatic tourniquet about the upper arm is blown up to 250 mm. to insure a bloodless field.



FIG. 7.—Two operating teams resurfacing two hands simultaneously.

The granulating surface is cauterized with 60% silver nitrate, applied on an applicator. The eschar which results, together with the peripheral zone of scar epithelium, is undercut and excised in one piece, using a large scalpel blade with a sawing motion, and taking care not to "buttonhole" the eschar.

In clean cases, the scar epithelium can be "peeled off" leaving all the dorsal veins and nerves intact if care is taken to find the correct line of cleavage at the beginning (Fig. 8). Any large bleeders (and there should be extremely few) are ligated with 000000 plain catgut ties.

Skin is removed with the Padgett-Hope dermatome (by preference from the back) and the large single sheets are modelled to the defect. When the entire breadth of the hand, including the thumb, is involved, two sheets are sewn together, with the suture line staggered to avoid a straight linear scar, which will contract. This graft is sewn on with a running suture of silk. The subsequent development of interdigital webbing is prevented by



FIG. 8.—“Peeling” off scar epithelium.

cutting the graft as shown in Figures 9 and 10. This places a maximum of tissue in the interdigital clefts, and places all the suture lines at right angles to the direction taken by the interdigital scar, which causes webbing. The grafts are not punctured, except in rare instances when the hemostasis has not been entirely satisfactory.

In clean cases, the hand is then dressed with long strips of gauze soaked in saline. In the potentially contaminated cases the gauze is soaked with liquid paraffin and one in ten sodium hypochlorite solution. These strips are carefully molded into the interdigital clefts and then continued beyond the tips of the fingers into the palm of the hand.

These strips are of such a width that the fingers are individualized, but nothing is packed down into the interdigital clefts (Fig. 11). While this dressing is being applied, and throughout the subsequent dressings, the wrist, metacarpophalangeal and interphalangeal joints are all held in approximately full flexion.

The palm is filled with fluffed gauze. The entire hand is then covered

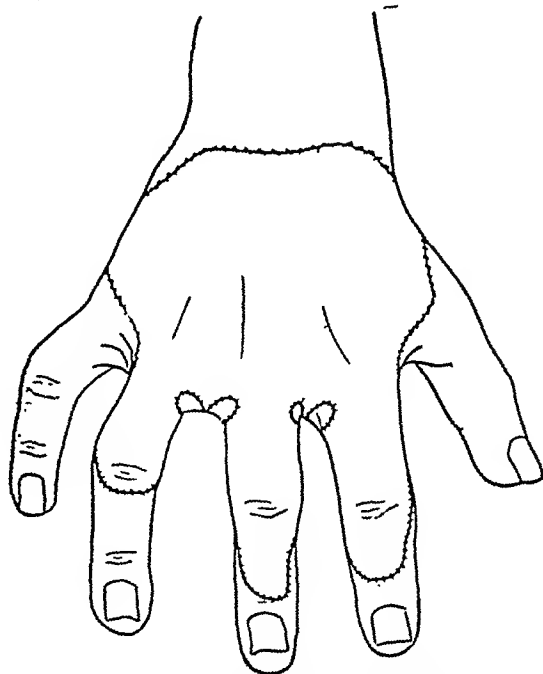


FIG. 9.—Cutting of graft in interdigital spaces to avoid subsequent webbing.



FIG. 10.—Cutting of graft in interdigital spaces to avoid subsequent webbing.



FIG. 11.—Individualizing finger with first layer of dressing.



FIG. 12.—Dressing completed.

## RESURFACING DORSUM OF THE HAND

with two thicknesses of dressing pads, the deep layer wet and the outer layer dry. The entire hand, forearm and distal half of the upper arm over the flexed elbow is then wrapped in a bias-cut flannelette bandage. This ensures light, even pressure. A light plaster of paris encasement is applied over this, completely enclosing the hand, and when this is firm, and not until then, the tourniquet is removed (Fig. 12).

The dressing is left untouched for 10 to 14 days, at which time it is removed and the stitches are taken out. After this the patient begins active finger exercises and massages the graft very gently with lanolin or cocoa butter.

It is noteworthy that these dressings are almost invariably completely dry when they are removed. Only when the dressings have been unevenly applied are there any superficial blebs, and only then are any subsequent dressings necessary.

It has been found that with the successful application of the above technic the indications for the use of pedicle flaps is steadily decreasing. They are now used only rarely.

One remaining indication for the use of pedicle grafts is in cases requiring free tendon grafts. Even in this group of cases there is one patient in whom two extensor expansions have been reconstructed on two fingers under dermatome grafts, and the remaining fingers are in the process of being similarly done.

By the use of this technic, a freely mobile, elastic surface can be produced. It is durable and does not break down. Full usefulness can be restored to all hands in which there is not irreparable joint damage.

The cosmetic result should be such that, after the elapse of about a year, it should be very difficult to discern the extent of the graft.

### SUMMARY

A technic for split-thickness grafting of the dorsum of the hands is presented.

By this method full restoration of the usefulness of the hand can be achieved unless there is irreparable joint damage.

A freely mobile, elastic and durable surface is restored.

The cosmetic result is excellent. It is, in the authors' hands, much superior to cases in which pedicle grafts are resorted to.

The indications for the use of pedicle grafts are steadily decreasing. They are employed on surfaces where the extensive replacement of tendons must subsequently be performed.

The use of pedicles is, of course, still indicated where a layer of fat is needed to fill out defects and for protection of important deep structures. In most instances, thick split-grafts or free full-thickness grafts have been used to resurface the palm or parts of the palm, and they have provided a resilient surface which has stood up to the trauma associated with manual labor.



# CHOLECYSTOGASTRODUODENOCUTANEOUS BILIARY FISTULA

## CASE REPORT

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EXTERNAL BILIARY FISTULAE are not uncommon but internal biliary fistulae are seen only occasionally and the correct preoperative diagnosis is seldom made. We wish to report an unusual case in which there were features of both internal and external biliary fistulae. In this case, there was no difficulty in observing the drainage of bile to the outside, but only surgical exploration revealed the surprising and unique feature of a concomitant cholecystogastroduodenal fistula. Partial gastrectomy, partial duodenectomy and cholecystectomy were performed, and a good result was obtained. The common bile duct was explored and drained.

Bernhard<sup>2, 3</sup> reported a series of 6,263 cases in which the biliary tract was explored. A biliary fistula was found in 109, or 2 per cent, of these cases. The gallbladder always was involved; the fistula was situated between it and the duodenum in 56 cases, between it and the colon in 36 cases, between it and the stomach in 12 cases, and there were multiple fistulous tracts in five cases. The causes of such fistulae are few. Usually, a stone, or stones, enter the intestinal tract by erosion of the mucosa and wall of the gallbladder and finally are passed, or actually cause intestinal obstruction, in a small percentage of cases. Varying degrees of inflammatory reaction necessarily accompany the ulceration, and in some instances, as in the case which we shall report, frank abscess of either the wall of the gallbladder or intestine is encountered. Stones large enough to cause such ulceration and obstruction never pass the full length of the common bile duct (Wakeley and Willway<sup>7</sup>), but erode through the wall of the gallbladder or bile duct. Rarely, a happy termination to a postoperative stricture of the common bile duct is occasioned by the spontaneous formation of an internal biliary fistula. The passage of the stones usually results in a short fistulous tract, but sometimes there is a direct opening between one element of the biliary tract and the stomach or intestine. Relatively few such cases (internal fistula by stone erosion) have been recorded in the literature.

The causes of external biliary fistula are well known. Balfour and Ross<sup>1</sup> reviewed 166 cases of biliary fistula observed at the Mayo Clinic and found that gallstones and their complications were primarily the cause of the condition in 85 per cent of cases. Since, in the case which we shall report, the

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\* Since this paper was written the authors have entered the armed services. Doctor Gray is now Captain, M.C., U.S.N.R., and Doctor Sharpe is now Captain, M.C., A.U.S.

surgical procedure was dictated by the possibility of ensuing obstruction at the outlet of the stomach if the mass of stones were left in the pyloric wall, and because of the indeterminate nature of the lesion, the literature concerning this phase of the problem was reviewed. The frequency of intestinal obstruction caused by gallstones varies widely. Vick<sup>6</sup> reported that such obstruction occurred in 47 (1.3 per cent) of 3,625 cases of gallstones, Osler<sup>5</sup>



FIG. 1.—Photograph of the surgical specimen showing the internal surface of the resected portion of the stomach with large gallstone lodged in the wall at the gastroduodenal juncture.

said that it occurred in 23 (7.8 per cent) of 295 cases, and McQueeney<sup>4</sup> said that it occurred in 149 (2 per cent) of 7,232 cases. The true diagnosis is rarely made; the patients are hospitalized late, and surgical intervention is instituted still later. McQueeney reported that the mortality rate in cases in which operation is performed for relief of such obstruction is about 50 per cent, usually because of the delay.

The treatment of internal biliary fistulae depends entirely on the findings in the individual case. The stones should be removed if possible. The fistula should be excised and the opening in the stomach or intestine should be closed. The gallbladder should be removed and the common bile duct

should be drained if there is any doubt as to its patency. Patency of the common bile duct should not be assumed in the absence of a history of jaundice, for the internal biliary fistula may have permitted adequate biliary flow in spite of the presence of stones in, or cicatricial narrowing of, the common bile duct. The danger of ascending infection, recurrent cholangitis, and hepatitis occurring in those cases in which spontaneous internal biliary fistula is not treated surgically has probably been exaggerated, for the most common type of internal biliary fistula involves the gallbladder and direct communication with the biliary tree is interrupted through the tortuous cystic duct and valves of Heister.

**Case Report.**—A blacksmith, age 58, came to the Mayo Clinic, February 10, 1941, because of an external biliary fistula which had been present for ten months. He had had pain and jaundice for the past ten days. Dyspepsia and pyrosis had been present for several years. About ten months previously, he had been operated upon for cholecystitis and cholelithiasis. There had been no previous jaundice. The operation had disclosed many stones in the gallbladder and an abscess which involved the wall of the gallbladder. The gallbladder had not been removed and the common bile duct had not been explored. Cholecystostomy had been performed and the stones had been removed. The postoperative course had not been abnormal except for the fact that drainage of bile had been profuse for the first two weeks. At the end of this time, the drain had been removed. A biliary fistula had occurred and bile-stained purulent material had been drained from the fistula. On several occasions, the patient had passed one or more stones. He had been able to work all summer as a blacksmith. His appetite had been good and his weight had remained constant.

About ten days before he came to the clinic, he had had an attack of epigastric pain, which had extended to his back and had lasted six hours. Jaundice had developed one to two hours after the onset of the pain, and at least one stool had been clay colored. The jaundice had deepened rapidly and had been most pronounced on the following day. Nausea and vomiting had been severe. He had had some fever but had not had any chills. The drainage of bile had been very profuse during the first few days after the attack; then it had ceased suddenly.

The patient was well-developed and well-nourished. The skin and sclerae had a mild icteric tint. Examination of the abdomen revealed a poorly-healed scar in the upper part of the right rectus muscle. In the upper third of the scar there were two or more granulomatous regions which had the appearance of recently healed sinus tracts. This portion of the scar was slightly tender. No mass was present and there was no drainage.

Examination of the blood did not reveal any abnormality. Urinalysis revealed pyuria, Grade 1, on the basis of 1 to 4, a flocculation test for syphilis was negative. The prothrombin time (Quick method) was normal. The van den Bergh reaction was direct, and the value for bilirubin was 1.3 mg. per 100 cc. of serum. It was thought that the patient probably was suffering from cholelithiasis, choledocholithiasis, or both of these conditions.

Operation was performed February 14, 1941. A large number of adhesions were found in the right upper quadrant of the abdomen. The gallbladder was chronically inflamed and contained several small stones. The fundus of the gallbladder was densely adherent to the duodenum and the sinus tract seemed to arise from this region. The common bile duct was about three times its normal size and contained normal bile as well as sandy and putty-like material. Scoops could be passed readily into the duodenum after some of this material had been removed from the ampullar region.

A T-tube was inserted in the common bile duct, and the gallbladder was removed from below.

In the region of the pylorus, the fundus of the gallbladder was attached, and a very hard, irregular mass, about 3 cm. in diameter, was felt. The exact nature of the mass could not be determined. Because of the age of the patient, the possibility of a malignant lesion and the certainty of future mechanical obstruction, it seemed advisable to perform a partial gastric resection and remove the mass in its entirety along with a small rim of the duodenum. Gastro-intestinal continuity was reestablished by means of a posterior Pólya type of anastomosis. The liver and pancreas were normal. A split-tube was left in Morison's pouch. The surgical specimen is shown in Figure 1. Examination of the specimen by a pathologist disclosed subacute cholecystitis superimposed on chronic cholecystitis. The walls of the gallbladder were moderately thickened and infiltrated. The gallbladder contained multiple stones which varied from 0.5 to 1 cm. in diameter. The other specimen contained 11.5 cm. of the stomach and 1 cm. of the duodenum. An inflamed cholecystogastroduodenal fistula, 3.5 cm. long, extended obliquely and distally from a serosal opening, situated 2 cm. proximal to the pyloric ring, on the anterior wall of the stomach, to a mucosal opening in the duodenum, 1 cm. distal to the pyloric ring. The fistula contained multiple stones, the largest of which was 1.5 cm. in diameter. Some of the calculi were as small as grains of sand.

The hard, irregular mass felt in the pylorus was the collection of stones. The cholecystogastroduodenal fistula was projected outward to the cutaneous border.

The patient again had an uneventful convalescence except for a slight separation and undermining of the skin edges of the wound at the level of the T-tube. He was dismissed from the hospital in good condition on March 6, 1941. The T-tube was still in place and was clamped at all times except for an hour after meals.

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# SOLITARY DIVERTICULITIS OF THE CECUM

## REPORT OF TWO CASES

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THE INABILITY TO DIFFERENTIATE acute appendicitis preoperatively, and carcinoma at operation, from the usual findings of an inflamed cecal diverticulum makes a consideration of this subject of prime importance. Baker and Carlisle,<sup>1</sup> in reporting 39 cases, found 14 radical resections had been carried out, many on a presumptive diagnosis of carcinoma. Preoperatively, all but four cases in which a diagnosis was made had been thought to be appendicitis of some type. The possibility of solitary diverticulitis of the cecum should always be considered when examining a patient who has had a previous appendectomy and who complains of right lower quadrant pain. Furthermore, when operating for appendicitis and finding an apparently normal appendix, a careful search for cecal diverticulitis should be made. Two cases of solitary diverticulitis of the cecum occurring in young males, which were encountered during a period of one year at a large station hospital, are reported.

## CASE REPORTS

**Case 1.**—A male, age 30, was admitted August 15, 1943. He stated he had been well until four days prior to admission. At that time he began having pain in the abdomen that was continuous and of mild to moderate intensity. The day of admission, pain localized in right lower quadrant. There was no nausea or vomiting, and no urinary symptoms. He took milk of magnesia the night before admission and his bowels moved the following day. His habits, family history and previous personal history were not remarkable.

*Physical Examination.*—This was normal with the exception of marked tenderness in the right lower abdominal quadrant, with some rigidity and spasm of muscles of this quadrant. Temperature 99.4° F.; pulse 76; respirations 18. Leukocyte count 15,000, with 76 per cent polys. Urinalysis—negative. *Diagnosis:* Acute appendicitis.

*Operation.*—Through a McBurney incision, the cecum and lower ascending colon was delivered and the omentum was found adherent to an inflamed area on the anterior, medial, wall of the cecum, at the junction of the terminal ileum with the cecum. Examination revealed an intensely inflamed diverticulum where the omentum was adherent, which had become suppurative and appeared to be the seat of a recent perforation. The attached omentum was divided from the mass and the entire mass was excised by an elliptical incision. The defect was repaired with a running Kerr stitch reinforced with a double layer of interrupted Dulox sutures. The appendix was removed. Five grams of sulfanilamide was deposited in the area, and the wound was closed in layers without drainage.

*Pathologic Examination.*—The specimen consists of a circular segment of large bowel to which there is attached a diverticulum. The tissue is swollen and friable. The specimen, after fixation, measures approximately 4 x 3 x 1.5 cm. On the mucosal side of the specimen there is an opening which communicates with the diverticulum. On sectioning, the diverticulum is seen to be markedly inflamed and necrotic. It is filled with a large fecalith, which has a diameter of approximately 0.7 cm. Sections showed

## SOLITARY DIVERTICULITIS OF CECUM

the diverticulum lined with typical large bowel mucosa. The muscularis mucosa is intact and the muscular wall of the diverticulum is also present. The entire wall is acutely inflamed and in some areas is undergoing necrosis. *Pathologic Diagnosis:* Acutely inflamed, necrotic, true diverticulum of the cecum.

Convalescence was uneventful, and the patient has continued on active duty, with no disability. Barium enema on November 8, 1944, showed no evidence of diverticula or pathologic changes other than those made at operation (Fig. 1).

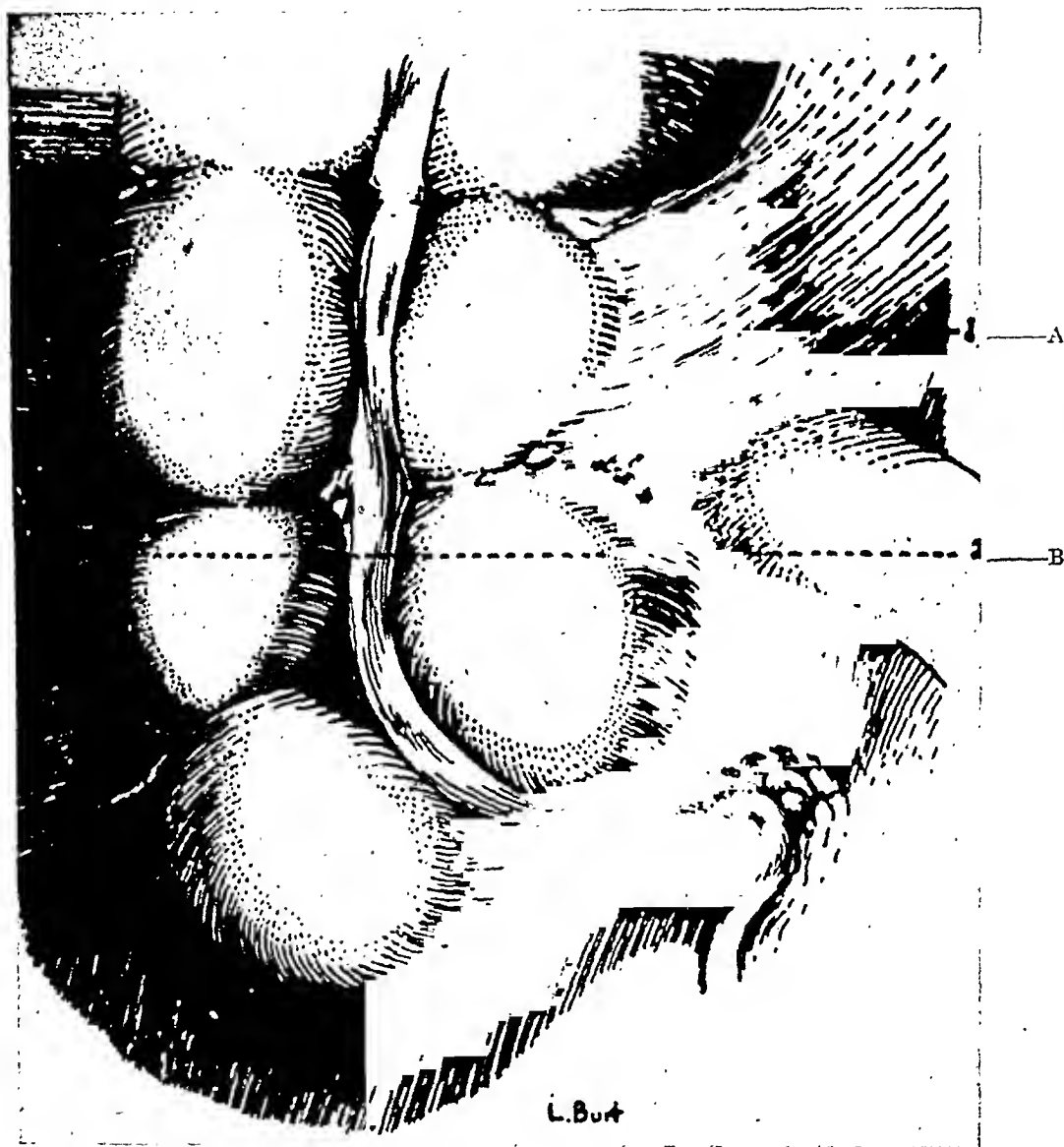


FIG. 1.—Diagrammatic sketch showing location of diverticula.

A. Case 1  
B. Case 2

**Case 2.**—A colored male, age 21, was admitted June 15, 1944. He stated he had been ill for the past four days with generalized pain in the abdomen. The pain remained generalized until the morning of admission, when it became more severe and localized in the right lower quadrant. He was not nauseated and did not vomit. In fact, he was able to eat as well during this period as at any other time. He had had no previous attacks of abdominal pain, and had been well most of his life, other than for moderate constipation. His habits and family history were negative. He had gonorrhea five years ago, and had been treated for syphilis. His Kahn test for syphilis was negative.

*Physical Examination.*—This was normal except for the abdomen, where there was marked tenderness in right lower quadrant, rebound tenderness, and muscle spasm. Temperature 99.8° F.; pulse 88; respirations 20. Leukocyte count 11,550, with 85 per cent polys. Urinalysis—negative. *Diagnosis:* Acute appendicitis.

*Operation.*—The abdomen was opened through a McBurney incision. Exploration revealed the appendix to be grossly normal. There was a palpable retroperitoneal mass, about the size of a hen's egg, on the lateral border of the cecum. Because of this, the incision was enlarged through a Weir extension. The cecum and lower portion of the

FIG. 2

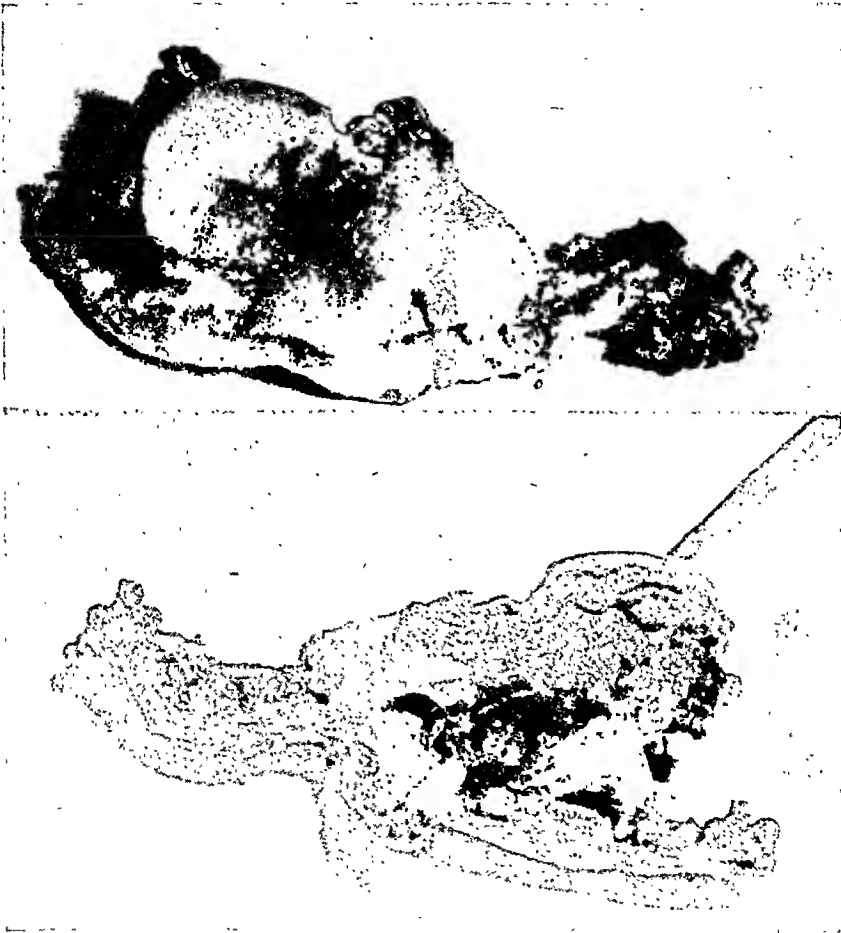


FIG. 3

FIG. 2.—Resected specimen. Case 2. Viewed from inside showing diverticulum.  
FIG. 3.—Resected specimen. Case 2. Viewed from outside with probe through perforation in diverticulum.

ascending colon were mobilized by dividing the lateral border of the peritoneum. This exposed the mass which appeared to be inflammatory. The remainder of the cecum and lower ascending colon appeared normal. After carefully dissecting through what appeared to be a thick layer of inflamed fatty tissue, the cause was found to be a perforated diverticulum. This was excised through an elliptical incision, and the defect repaired by continuous Connell suture, reinforced by interrupted Lembert sutures. The appendix was removed, five grams of sulfanilamide placed in the abdomen, and the wound closed in layers after inserting one Penrose drain.

## SOLITARY DIVERTICULITIS OF CECUM

*Pathologic Examination.*—The specimen consists of a spherical piece of large bowel wall. After fixation, this specimen measures approximately 3 x 2 cm. Directly in the center of this tissue there is an opening, which measures approximately 3 mm. in diameter. This opening leads into a diverticulum. This diverticulum is perforated at its attachment to the bowel wall. Surrounding the diverticulum, there is a marked inflammatory reaction (Fig. 2). The wall of the diverticulum on cut-section is seen to be necrotic. Sections showed the diverticulum lined by typical large bowel mucosa. The muscularis mucosa is intact excepting for the region in the area of the perforation;



FIG. 4.—X-ray of barium enema. Case 1. 14 months after operation.

the muscularis is absent. The wall of the diverticulum is seen to be necrotic, and there is an acute inflammatory reaction present. The acute inflammatory process is diffuse throughout the wall of the diverticulum, but is most marked in the perforated area (Fig. 3). The inflammatory process has spread to the attached soft tissue. Examination of the appendix revealed a subacute diffuse inflammatory process. *Pathologic Diagnosis:* (1) Acutely inflamed, perforated, false diverticulum of the cecum. (2) Subacute diffuse appendicitis.

Convalescence was uneventful. The drain was removed on the fourth day, and the wound healed *per primam*. Barium enema, August 24, 1944, showed no evidence of



other diverticula, or pathologic changes other than made at operation (Fig. 4). He returned to combat duty.

Case 1 represents the congenital, or true type, of diverticulum, as distinguished by being made up of all the normal layers of the large intestine. Case 2 is the acquired, or false type, the muscularis being absent (Fig. 5).



FIG. 5.—X-ray of barium enema. Case 2, 2 months, 9 days after operation.

The first case report of a patient with diverticulitis of the cecum was made by Portier<sup>2</sup> in 1912. In 1942, Schnug<sup>5</sup> found 32 cases, and reported six of his own—a total of 38. In 1943, Baker and Carlisle<sup>1</sup> reviewed the American and British literature for the past 20 years, and found 37 cases, adding two of their own. Carroll,<sup>2</sup> about the same time, searched the literature, and reported 43 collected cases, to which he contributed one. Shortly following this, Fritz<sup>3</sup> added one case.

There is little in these reports that aids in differentiating this condition

preoperatively from acute appendicitis—the diagnosis most frequently made. Other preoperative diagnoses included appendiceal abscess, acute gangrenous appendicitis, perforating appendicitis, subacute appendicitis, chronic appendicitis, stump appendicitis, carcinoma of the cecum, and obturator hernia. The correct preoperative diagnosis was made on one patient. The temperatures varied from 97.4° F. to 102° F., Leukocyte counts from 6,000 to 23,000. The only symptom almost always present was tenderness in right lower quadrant of abdomen. Age was of value only in that a higher percentage were under 40 years, than in cases of multiple diverticulitis. Operative procedures included: drainage, local excision, inversion, extraperitonealization and partial ileocelectomy. The latter was performed a rather large number of times on a mistaken impression of process being malignant. The results of treatment were rather remarkable, in that there were only two deaths. Schnug,<sup>5</sup> in concluding, states: "A radical excision of the mass by resection and anastomosis is definitely not indicated. A local excision and closure of the defect in most cases is probably not advisable. Except in those cases which have developed an abscess, and in which drainage is indicated, the abdomen should be closed without doing an appendectomy and without drainage, and chemotherapy be instituted."

COMMENT.—Since the right lower quadrant of the abdomen is approached surgically so frequently, it is well for surgeons to keep this condition in mind, because in most cases local excision is all that is required to produce a permanent cure. This is in contradistinction to multiple diverticulitis, where most treatment is palliative. However, as pointed out by Jonas,<sup>4</sup> very large, inflamed diverticula lying close to the ileocecal valve, or between the leaves of the mesentery, so as to jeopardize the cecal blood supply, require extensive resection including, usually, the terminal ileum, cecum, and ascending colon, with anastomosis between the ileum and transverse colon.

The two cases here reported differed from Schnug's<sup>5</sup> experience, in that after excision of the diverticulum, the tissue edges of the bowel were remarkable because of their normalcy and the ease with which a firm closure was obtained. In fact, this was one of the most distinguishing features at operation; that is, the surrounding bowel in appearance and on palpation seemed so normal.

The symptoms and signs in the two reported cases were not such that they could be differentiated from appendicitis, and in this way agree with most reported cases. The lack of nausea and vomiting and the length of illness (four days) might suggest an atypical appendicitis, but certainly nothing further. Preoperative roentgenologic studies, besides being dangerous, would, in many cases, be of little value because frequently the diverticulum is filled with a fecalith, and would fail to visualize.

It is felt that associated appendectomy, with local excision of the diverticulum, is justified, and does not increase the risk appreciably. In one of the cases reported, the appendix, microscopically, showed a diffuse inflammatory process and, if allowed to remain, would no doubt have caused trouble. The other was entirely normal.

## CONCLUSIONS

1. The importance of differentiating solitary diverticulitis of the cecum from carcinoma, at operation, is demonstrated.
2. Inability to differentiate this condition preoperatively from appendicitis has been pointed out.
3. Local excision of an inflamed cecal diverticulum will, in most cases, result in a permanent cure, and associated appendectomy is indicated.
4. Two cases of solitary diverticulitis are reported.

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# A CONTINUOUS TRACTION SCREW FOR FIXATION OF FRACTURES OF THE HIP

REVIEW OF 23 CASES

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IN the treatment of fractures of the femoral neck, the authors have found a traction screw (designed by Virgin) to be a particularly efficient form of internal fixation. This appliance embodies a new feature consisting of a special spring arrangement that provides for a *take-up* in the event of absorption about the fracture line. Continuous apposition of the fractured surfaces is thereby ensured. A sufficient number of cases have been treated by the continuous traction screw, over a five-year period, to constitute a basis for end-result study.

## DESCRIPTION OF THE TRACTION SCREW (FIG. 1)

The screw may be made of 18-8 stainless steel or of vitallium.

The leading end of the instrument is made up of deep cutting threads, the design of which should be credited to Professor Howard Becker, of the University of Wisconsin. The threads are thin, and the roots cut deep, so that the maximum amount of unbroken cancellous bone is grasped between each two threads. In this way the screw is provided with great holding power, and the pull is spread over several square inches of thread surface. The leading cutting thread permits the screw to cut itself into position as the operator turns it. The edge of the last large thread is designed to cut its way backward to permit the removal of the screw.

The shaft is so strong that a powerful man cannot bend it. On the lower end of the shank is a washer, a spring, and a nut, arranged in order from above downward. The spring is so designed that it collapses within itself and takes up the minimal amount of space. Yet, the spring is capable of exerting a ten-pound continuous pull that provides for a *take-up* of five-eighths of an inch. The washer protects the femoral cortex from the sharp edges of the spring, and spreads out the traction force at the cortex, which is used as the base for the pull. Close to the end of the screw is threaded the nut, on standard threads, which allows for adjustment as to length during the fixation. The nut also provides for a *take-up*, allowing the spring to be tightened and reactivated in case the absorption of the femoral neck should total more than the five-eighths of an inch for which the spring provides. Finally, the end of the shank is squared-off to take a tap wrench chuck. The threads, however, are continued to the very end of the squared-off section, so that, if necessary, the nut can be backed to the end of the shank.

The only tools necessary for the insertion of the screw are a drill, of one-half-inch diameter, for opening the femoral cortex, a tap wrench with a one-quarter-inch chuck to receive the squared-off shank, and a one-half-inch T-handled socket wrench for tightening the nut. Ordinary pliers may be used in place of the wrench to turn the screw.

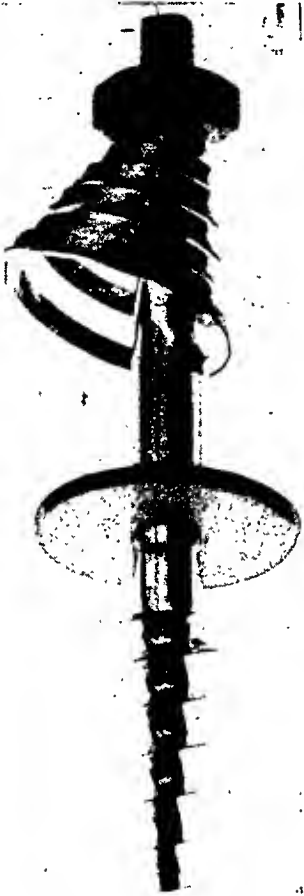


FIG. 1.—The continuous traction screw.

#### TECHNIC OF APPLICATION

The technic of introducing the traction screw is essentially the same as that of inserting other fixation agents. Its insertion is extremely simple and may be carried out within from 20 to 30 minutes, even when correction of the position of the screw is required. Throughout the process of insertion, it is necessary to check repeatedly by roentgenograms both the direction and position of the screw. The roentgenograms should be taken in both the anteroposterior and lateral planes.

The length of the screw to be used is determined as follows: On an anteroposterior roentgenogram of the uninjured hip, the distance from the apex of the femoral head to the base of the greater trochanter is measured, and one-quarter of an inch is added to this measurement.

The preoperative preparation is carried out in the routine manner. Spinal anesthesia is used. The fragments are first accurately reduced, and the position is checked by roentgenograms taken in both the anteroposterior and lateral planes.

A simple guide for directing the screw is provided by the surface of the operating table, when the leg is maintained in the position of internal rotation during the introduction of the screw. Normally, as the patient lies on his back, the junction of the femoral neck and shaft falls backward. There is, therefore, a declination lateralward of the neck from the head, and the greater trochanter lies below the horizontal plane passing through the center of the femoral head. When the leg is rotated internally until the femoral neck lies parallel with the plane of the table, usually to an angle of 45 degrees, the greater trochanter rises from the table, and the plane running horizontally through the femoral head cuts through the center of the neck and the greater trochanter. This simple guide provided by the surface of the table, as well as the surgeon's knowledge that the femoral neck and shaft join at an angle of 127 degrees, facilitates the introduction of the screw.

A longitudinal incision is made in the skin on the lateral aspect of the thigh, extending downward from the region of the greater trochanter, and of sufficient length to allow easy approach. The subcutaneous tissues are

divided longitudinally by sharp and blunt dissection until the periosteum is exposed. Just below the greater trochanter, the periosteum is divided with a periosteal elevator, exposing the cortex.

The site for the entry of the drill is now determined as follows: The junction of the greater trochanter and the upper end of the femoral shaft is located. Here an arc extends gradually upward and outward from the shaft toward the overhanging greater trochanter. A line drawn through the center



FIG. 2.—Roentgenogram of a case in which there was no absorption of the femoral neck, and, hence, no expansion of the spring.

of the femoral head cuts the center of this arc perpendicularly. The area on the lateral surface thus determined provides a relatively flat surface, at a right angle to the long shaft of the screw, on which to butt the washer and spring. In this way the best area for the proper spread of the pressure is obtained. At the center of the arc, the surgeon makes an aperture in the cortex with a one-half-inch drill.

The shank of the screw, with the washer, spring, and nut in place is fitted into the chuck of the tap wrench. The large threads of the screw are inserted into the drill-hole for about an inch, in the direction of the center of the femoral head, and the screw is turned until the leading threads lie within the confines of the bone. Anteroposterior and lateral roentgenograms

are taken to check the direction of the screw. Any necessary correction can be made by manual force for as much as 30 degrees in either the antero-posterior or lateral plane, such correction being possible because of the porosity of the cancellous bone, the strength of the shaft of the screw, and the thin and cutting quality of its threads. The screw is then turned into its final position, with the leading cutting thread stopped about one-quarter

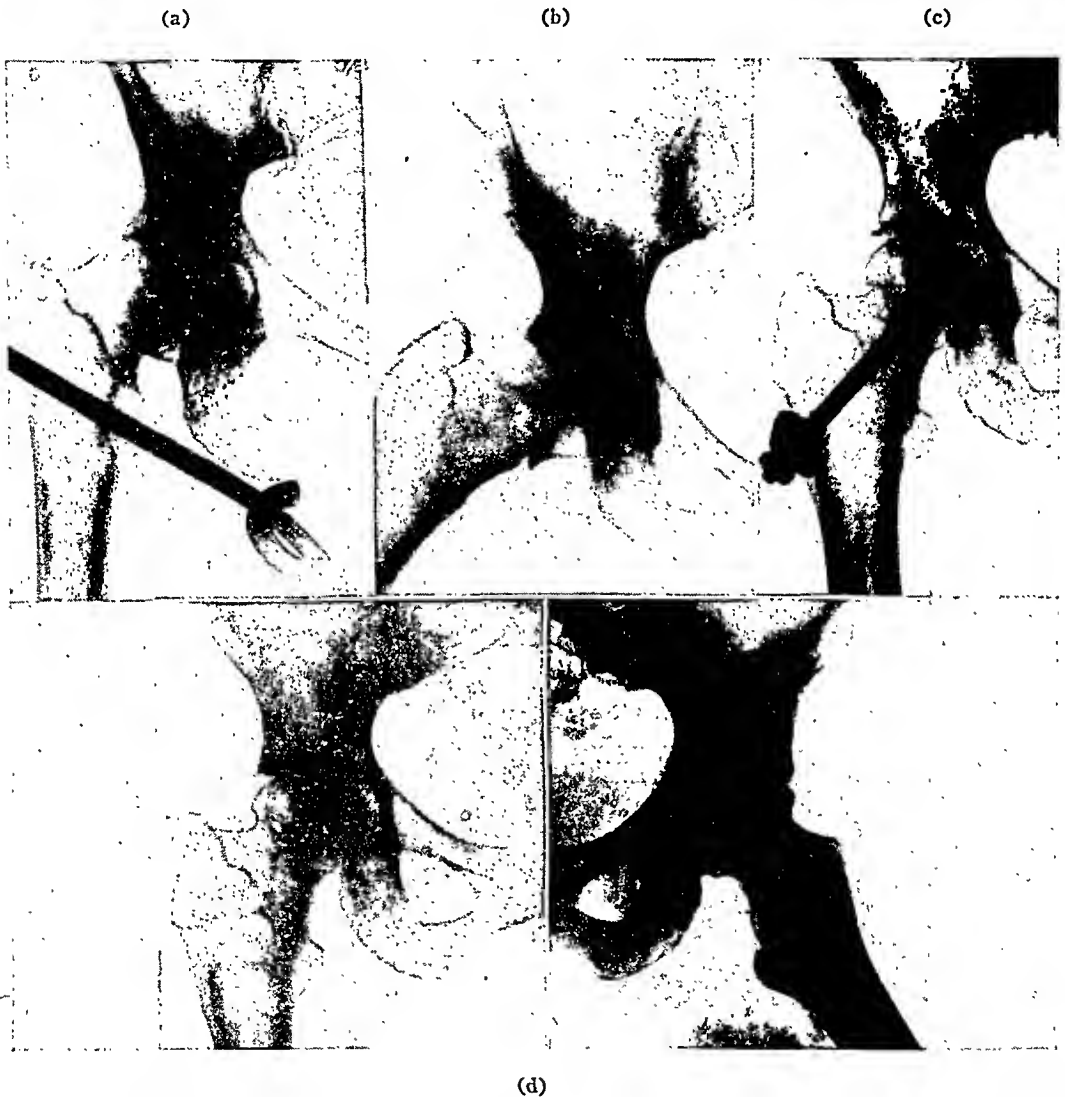


FIG. 3.—Case, S. E., in which there was slight absorption of the femoral neck, with a corresponding slight expansion of the spring.

(a) The original fracture.

(b) Roentgenogram following reduction.

(c) Screw in position seven months after reduction, showing slight expansion of the spring.

(d) Anteroposterior and lateral roentgenograms taken two years after the fracture.

of an inch from the apex of the head. It must be clearly understood that none of the large leading threads protrude from the head fragment, since this would defeat the pulling action of the spring. In other words, the fracture line must lie on the smooth, polished shank of the screw, so that in the event of absorption, the shank of the screw can slide, or be backed out,

## CONTINUOUS TRACTION SCREW



FIG. 4.—Case, M. R., in which the spring expanded nearly to its full extent to take up the absorption of the femoral neck.

(a) The original fracture.

(b) Roentgenogram following reduction.

(c) Screw in position four months after reduction, showing expansion of the spring.

(d) Anteroposterior roentgenogram taken four years after the fracture, showing bony union with absorption of the femoral neck, necrosis of the head, and arthritic changes.



by the action of the spring, in order to pull the head fragment down onto the shaft. The surgeon is aided in controlling the depth by his knowledge that six complete turns of the screw advance it for a distance of one inch. The position and progress of the screw are guided by roentgenographic examination.

The soft tissues are separated by retractors to allow the washer to impinge against the bone. At this stage the spring is usually collapsed. The nut is adjusted with the socket wrench in order to impact the fragments. Considerable manual effort must be exerted to tighten the nut, but there need be no fear of pulling out the screw.

In case the screw is found to be too long, its progress should be stopped at a point one-quarter of an inch from the articular surface, even though the spring has not collapsed. The nut is then turned down on the shank until the spring collapses. If the screw proves to be short, the tap wrench is removed, and the nut turned backward until it comes to within one-eighth of an inch of the end of the shank. The tap wrench is again applied and turned until it is tight, collapsing the spring. The nut is tightened to impact the fragments. This process may be repeated, if necessary, allowing a gain of from three-eighths to one-half of an inch, until all the large threads lie in the head fragment.

The next step is to move the extremity freely in all directions. In this way the surgeon may demonstrate not only that the fixation is firm, but also that the hip motion is free.

Closure of the wound is carried out by allowing the deep tissues to fall together over the spring and the protruding end of the screw, and then suturing them with a single, or at the most, with two loose stitches of catgut. All dead spaces are closed with loose interrupted sutures, and the skin is closed with interrupted silk sutures. A dressing is applied, and the motion is again tested.

#### POSTOPERATIVE CARE

When the patient recovers from the anesthesia, it is well to demonstrate to him that the artificial union is strong and that the joint can be moved freely. At the same time, it should be explained that the screw is not to be considered a substitute for bone. On the second day, the surgeon should again move the hip, trying to obtain the cooperation of the patient.

The patient is permitted to move about the bed at will and the nursing care may be carried on in the usual manner. Contraction of the quadriceps muscle should be practiced while the patient lies in bed, to promote the circulation and muscle tonicity. On the third postoperative day, the patient is encouraged to begin active motion by sitting on the edge of the bed and extending the knee. Wheel chair privilege may also be extended about this time. At the end of the first week, the patient may begin to walk with the aid of crutches, keeping the injured foot off the floor. Walking with crutches is made easier if the patient first practices standing by steadying himself with

## CONTINUOUS TRACTION SCREW

the toe of the injured extremity touching the floor, and by attempting to walk about the end of the bed, bearing weight on the well leg and dragging the injured limb. At any time after the operative reaction has safely passed, the patient may go home.

Unqualified weight-bearing is not allowed until the roentgenograms show good bony union. This is usually from the fourth to the sixth postoperative month. In view of the uncertainty of the duration of the healing period, it is well to refrain from discussing the time of weight-bearing with the patient.



FIG. 5.—Roentgenogram of a case with destruction of the femoral neck, in which the spring took-up approximately seven-eighths of an inch of absorption.

When the union is solid, the screw may be removed. No difficulty is encountered in its removal, even though the screw is held tightly in the bone.

### INDICATIONS FOR THE USE OF THE SCREW

The screw may be used in treating the subcapital fracture, and the transcervical fracture in either the midneck of the femur or at its base.

In the selection of fractures for screw fixation, the patient's age and general condition must be considered. Extreme senility is not a contraindication, provided the general condition is fair. The fact that the introduction of the screw is easy and requires little time, as well as the early postoperative activity made possible by such fixation, warrants considering the procedure in elderly patients. The oldest patient in the series of cases being reported was age 89.

## ADVANTAGES OF THE CONTINUOUS TRACTION SCREW

By the nature of its design, the traction screw satisfies all the recognized principles of efficient internal fixation. It is easy to insert, because the screw cuts itself in, requiring no guide or reaming of the bone, and no blows to position it. Under such circumstances, the shock is minimal, and there is little traumatization of the soft structures and bone tissue, which ensures better preservation of the blood supply to the femoral head and neck.

The screw meets the requirements of rigidity in a fixation agent. It is strong and there has been no instance of its breaking or bending. Throughout the entire healing period, it remains fixed in place, making it possible for the patient to be cared for easily and to resume activity early. The danger of the development of pulmonary complications is lessened, the patient is more comfortable, and the period of hospitalization is shortened. So complete is the immobilization obtained by the screw that the patient may be ambulatory with the aid of crutches within a week.

Close coaptation of the fragments is ensured, when the fractured surfaces are forced together, by the grip of the large cutting threads on the femoral head. There is no danger of pulling the screw loose from the head, since in its introduction, no segments of bone between the threads are broken off, and the pull is spread through the entire depth of the fragment. The firm apposition and impaction of the fragments prevent any rotation of the femoral head on the screw.

Not only is close apposition of the fragments ensured by the continuous traction screw, but actual *pressure* contact of the fractured surfaces is established. By means of the special spring embodied in the screw, this pressure is exerted throughout the entire healing period. As late as six months following the fracture, when the screw may be removed, the spring is found to be still maintaining some pressure.

By means of the spring arrangement, the fragments are maintained in apposition, even though absorption takes place at the site of the fracture. Herein the traction screw has its greatest advantage over other fixation appliances. Many of the immobilizing agents in use at present are of the screw-bolt type, their originators having recognized the limitations and defects of nail and wire fixation, due to traumatic introduction, slipping, and the failure to maintain close apposition of the fragments. Outstanding among the screw-bolt appliances are those designed by Henry, Lippmann, Henderson, Putti, and Godoy-Moreira. None of these methods, however, provides for continuous internal traction in the event of absorption.

## ANALYSIS OF CASES

During the period from March, 1939, to March, 1943, the continuous traction screw was used in 23 cases. Nineteen of the patients were females. The ages ranged from 43 to 89 years; six were over 80 years of age, and eight were in their seventies.

There were complications in eight cases. Two patients were unbalanced mentally, and one of these patients had an arthritic knee on the injured side.

Three patients had had cerebral hemorrhages, and one had had hypertension. One patient had a fracture of the femoral shaft on the injured side, and one patient had had a coronary attack and also was arthritic.

*Results.*—Six cases were deleted from the series of 23 cases. One of these patients, age 89, died within a few days of the operation. One patient died of cardiac failure a few months after the operation. Two patients died six months after the operation, one from pneumonia and the other from a cerebral hemorrhage. Two patients had been unable to report for a late roentgenographic examination, because they lived at a great distance from a hospital.

The results in the remaining 17 cases were estimated after a postoperative lapse of from one year and eight months to four years. The standard for a successful result was considered to be bony union with a minimum necrosis of the femoral head, good function with strength, walking with comfort, and freedom from pain. Clinically, 12 of the 17 patients obtained excellent or good results, as measured by the accepted standard. In three cases the results were only fair; two of these patients were confined to wheel chairs because of cerebral paralysis, and one had a good functional hip, but the motion was painful. In two of the cases in which nonunion resulted, the functional outcome was poor.

Bony union took place in 13 of the 17 cases, giving the percentage of 76.8. In only two cases was there appreciable necrosis of the femoral head. Varying degrees of absorption of the femoral neck occurred in five cases, and complete absorption in one case. In all instances the spring device proved to be effective in maintaining the apposition of the fragments.

#### SUMMARY

The principle of continuous internal traction in the treatment of fractures of the hip appears to have been demonstrated for the first time.

In the series of cases that has been reported, the especially designed screw has demonstrated its effectiveness in providing for a *take-up*, and in maintaining the apposition of the fractured surfaces, when absorption of the femoral neck occurred.

This fixation instrument also meets adequately all the requirements of good internal fixation, including simplicity of insertion, firm apposition of the fragments, and rigidity.

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# RECURRENT INGUINAL HERNIA

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IT IS SURPRISING to find that in the voluminous literature on inguinal hernia, the articles on recurrences and the operative repair of recurrent inguinal herniae are relatively infrequent. In a good many of the textbooks and systems of surgery the subject is scarcely mentioned. Yet the correct surgical approach to this subject requires a great deal of judgment and experience, and not inconsiderable effort to effect a cure.

In this communication we wish to review our experiences with the methods of repair, and the types of recurrences encountered, and analyze the follow-up results in our series of 126 cases. It is felt that an analysis of the basic types of recurrent herniae encountered, together with the selection of a suitable operative procedure in each instance, will be of aid in guiding one's plans as to the type of repair to be carried out, and will reduce the incidence of secondary recurrences.

Statistics relating to the incidence of recurrence following primary herniorrhaphy vary a great deal. In most instances the recurrence rates average about 5%, although isolated series have been reported as low as 0%, and as high as 21%. It should be stated here that we feel that any hernia recurring at the site of the previous inguinal hernia repair should be considered a recurrent inguinal hernia, and we have so classified our cases. A good many surgeons feel that a high percentage of so-called recurrences are really incisional herniae, muscle-bulging due to weakness, *etc.*, and are not true inguinal herniae. However these herniae, whatever we may call them, are a result of the primary operation and in that sense are recurrences. It is also notable that these are prone to secondary recurrences. This variation in terminology accounts for some of the differences in statistical figures. The figures relating to secondary recurrences are difficult to find. These vary from 0% to 26%; and an approximate average is difficult to determine.

The present review consists of 126 cases, with 129 operations for recurrent hernia. In this group 72% were followed up to three years. It is interesting to note that four patients presented themselves with recurrent herniae which had previously been twice repaired, two in which three previous herniorrhaphies had been done, and one in which four repairs had been done. The recurrence rate following repair of this group of 126 cases was 3.1% or four cases.

# RECURRENT INGUINAL HERNIA

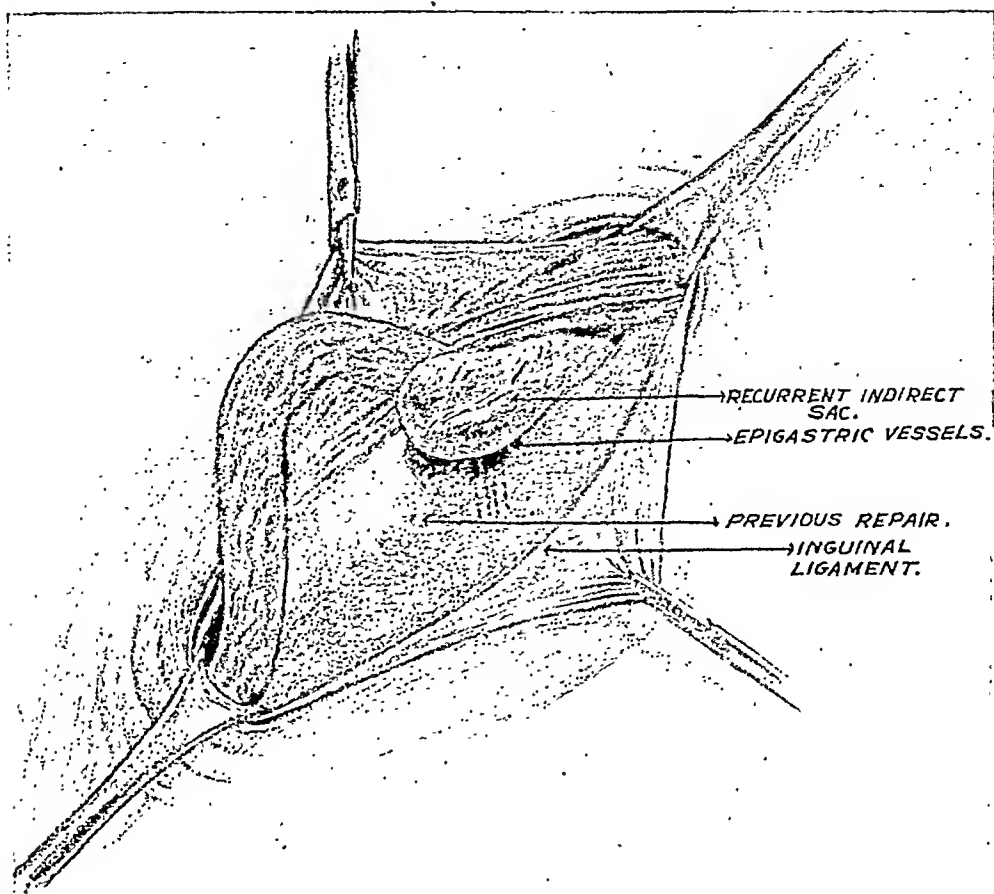


FIG. 1.—Indirect sac recurrence.

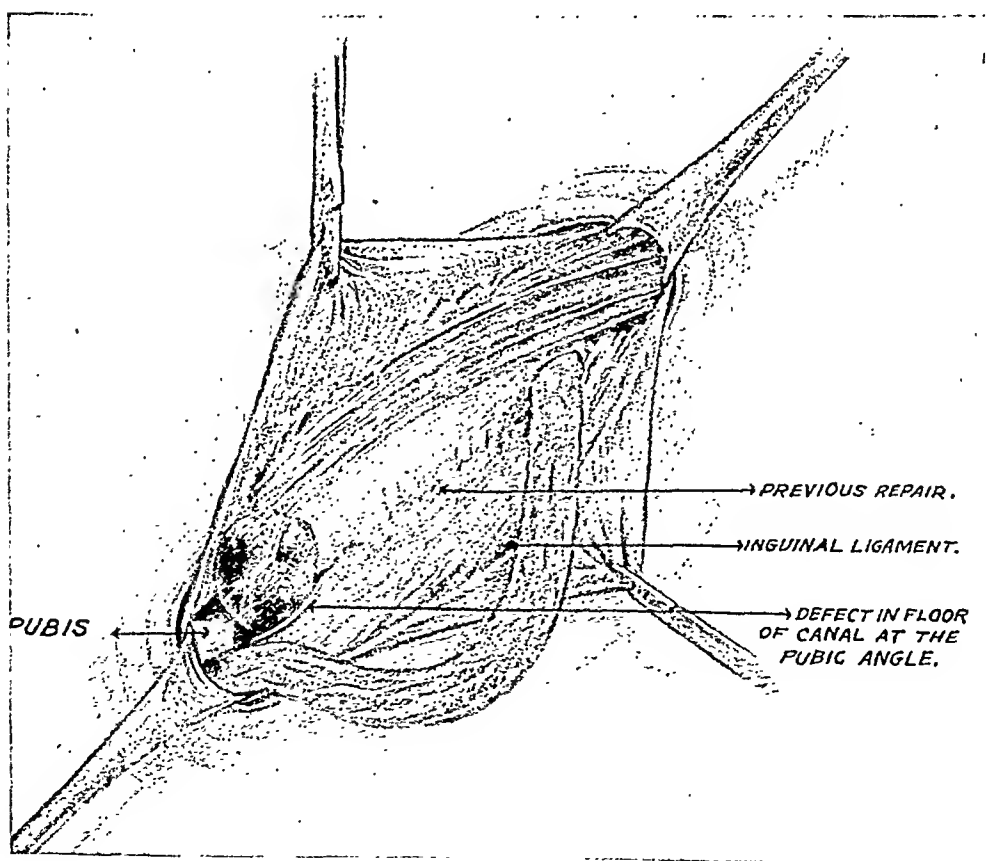


FIG. 2.—Direct recurrence at pubic angle.

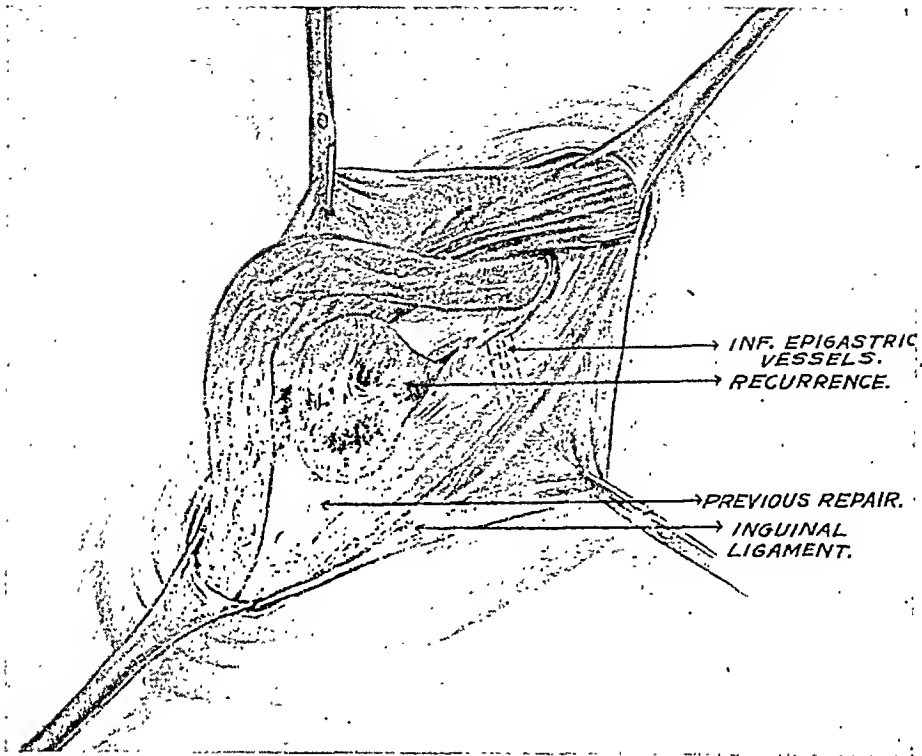


FIG. 3.—Recurrence between suture lines.

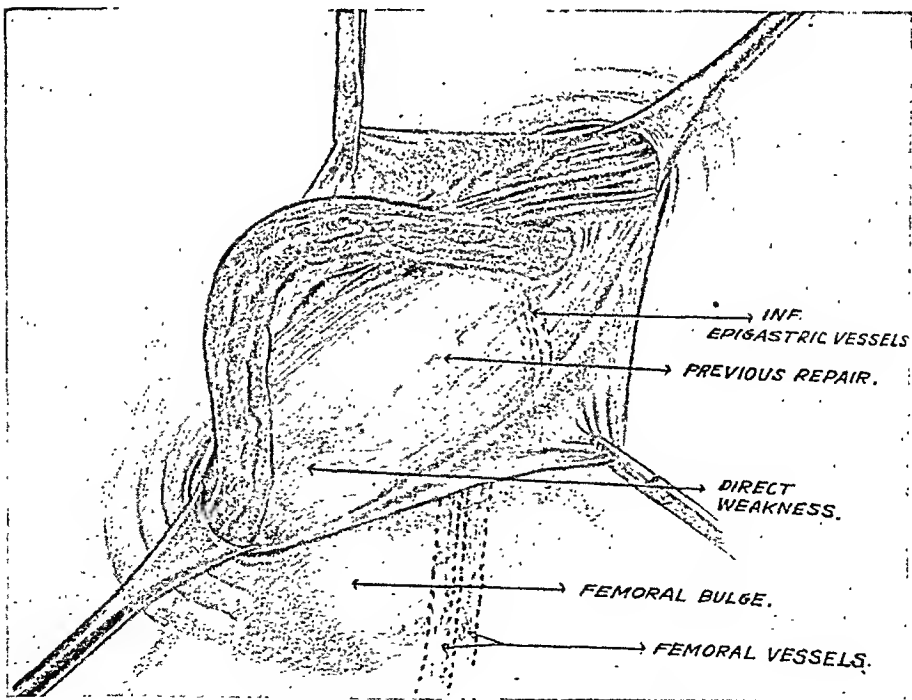


FIG. 4.—Combination direct and femoral recurrent hernia.

## RECURRENT INGUINAL HERNIA

### CAUSES OF RECURRENCE

The cause of recurrence following primary or even secondary repair is of interest in discussing this subject. A number of factors have been indicted as contributing to recurrence and may be listed as follows:

1. *Body Build*.—This would include poor musculature; the absence or obliteration of the conjoined tendon; and the stretching out of fascial structures.

2. *Systemic factors*, such as coincidental disease; anemia; and recent weight loss and debility.

3. *Local Factors*.—These are probably the most common offenders and include the breaking of sutures, perhaps due to insertion under tension; the failure to obtain fascial approximation due to the interposition of fat or muscle; the failure of incomplete removal of the sac; the presence of hematomata; nerve injury and resulting muscular weakness. Postoperative cough and tension; and direct trauma. To this we would like to add the practice of bilateral, one-stage operation, as it has been shown in another paper that the incidence of recurrence is increased 13.5% by this procedure.

4. *Type of Work*.—The incidence of recurrence has been found in some series to be increased in those individuals doing heavy work with subsequent trauma and physical exhaustion.

In a group of 1126 primary hernia repairs our over-all incidence of recurrence was 1.89%; 1.94% for indirect; and 1.85% for direct herniae. These have been reported elsewhere.

### CAUSE OF SECONDARY RECURRENCE

The attempt has been made to estimate the major factors involved in secondary recurrences following recurrent hernia repair. It is our feeling that a good many secondary recurrences are the result of extremely poor structures encountered together with an inadequate repair or a poor choice of manner of repair. When operating upon recurrent hernia we expect poor structures—and this should not be a cause for recurrences, if the repair is correct. Infection may play a larger rôle in this type of hernia because of the dissection involved, and the presence of scar and partially devitalized tissue. Severe cough, pneumonia, and upper respiratory infections play a rôle and should be controlled or prevented if possible. The coöperation of the patient regarding postoperative rest and convalescent care is more necessary and must be more prolonged following these repairs. Direct trauma may also play a part. In one instance that we recall the secondary recurrence was caused by a fall on a sharp object. Two other secondary recurrences in our series were due to infection. The cause of the recurrence in the fourth case was not determined.

### THE TYPES OF RECURRENCES

The types of recurrences encountered in this series were rather varied, but would all fit into one of the forms shown in Figures 1 to 6. Almost all of the primary repairs had been done elsewhere, so that the actual method



of original repair was not known or tabulated, but it is our recollection that at operation the usual three basic varieties (regarding the position of the cord) were encountered. In several instances a previous fascial repair had been done.

The recurrence of the indirect inguinal hernial sac (Fig. 1) was fairly frequently encountered, and is a little hard to evaluate. It may be that some indirect sacs were not removed at the primary operation, but we do not feel that this was a very common cause. Perhaps the closed neck of the sac reopened following strain or tension, and left a peritoneal defect, with subsequent protrusion of abdominal contents and reperitonealization of the contiguous structures. In some instances the forming of a superimposed internal and external ring (as in the original Halsted repair), loosely closed may have allowed the peritoneum and contents to bulge and reform a hernial sac. In order to prevent the pulling out of sutures about the neck of the hernial sac and to prevent direct bulging out through the external and internal ring, we sometimes vary our method of closure of the neck of the sac and arrange the cord so there is a "staggering" of the internal and external ring. In the primary repair of the combined indirect and direct, or "pantaloon" hernia we do not as a rule use a purse-string suture or transfix the stump of the sac high under the internal oblique muscle because of the tension involved and subsequent danger of the sutures pulling out and, thus, leaving a peritoneal defect.

The recurrent hernia at the pubic angle (Fig. 2) is quite common, and is probably due to poor structures, the breaking of sutures due to excess tension, and the postoperative distension of the bladder. The careful placing of sutures without tension, a relaxing incision in the rectus sheath if necessary, and reinforcement with some type of fascial suture at the time of primary repair would largely aid in preventing this recurrence.

The recurrence due to an opening in the suture lines (Fig. 3) is a ventral postoperative hernia of the inguinal canal. Its causative factors are similar to those of any incisional hernia.

The combined recurrent hernia in the direct and femoral regions (Fig. 4) is not too common, and is somewhat more difficult to repair. It is felt that this hernia is commonly due to a weakening of the femoral region at the time of primary repair. It can be readily shown at operation that a suture joining the shelving edge of the inguinal ligament and the conjoined tendon lifts up the inguinal ligament, and, without any question, enlarges and tends to open up the femoral canal. This type of reconstruction is not an anatomic one. If, instead of the shelving edge the reflexion—the folded portion of the ligament farther anteriorly on the edge of the ligament—is used, the shelving edge is not displaced and weakening does not occur. An equally efficient repair is obtained.

The recurrent hernia (Fig. 5), characterized by a general weakness along the inguinal ligament, with the general bulging of preperitoneal fat and peritoneum beneath a large part or all of the inguinal ligament, is not common,

but does occur (seven cases in this series), and is extremely difficult to repair. It is felt that this is due to the use of the shelving edge of the ligament, as described above, together with a stretching and loosening of the entire ligament. In such instances the inguinal ligament is of little or no value as a structure to be used for repair.

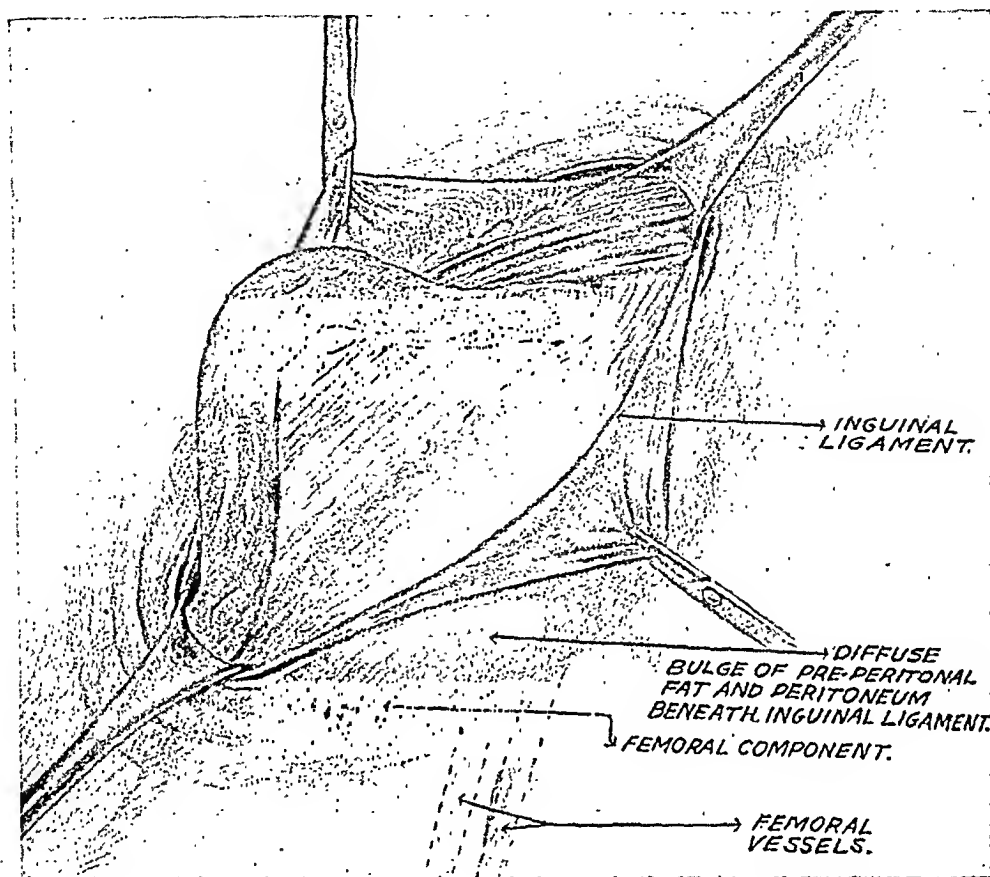


FIG. 5.—Modified femoral recurrence with general bulge beneath inguinal ligament.

In describing the types of recurrences listed above we wish to state that these are considered basic types, from which variations occur. Every recurrent hernia encountered is different, but if the basic type can be determined at the time of operation, we feel that the logical plan for the most efficacious type of repair can be readily determined. We do not feel that any one type of repair can be suitable in all instances.

#### METHODS OF REPAIR EMPLOYED

The methods of repair of inguinal hernia have about covered the range of possible procedures. While not listed this is also probably true of procedures used for recurrences. Our procedures have been limited to the employment of various reconstructive and fascial procedures from about the inguinal region itself together with the use of tissue from the fascia lata. Periosteal flaps, muscle transplants, *etc.*, have not been used. In some instances heterogeneous tissue such as ox fascia has been used but it is not felt to be as good as autogenous fascial material.

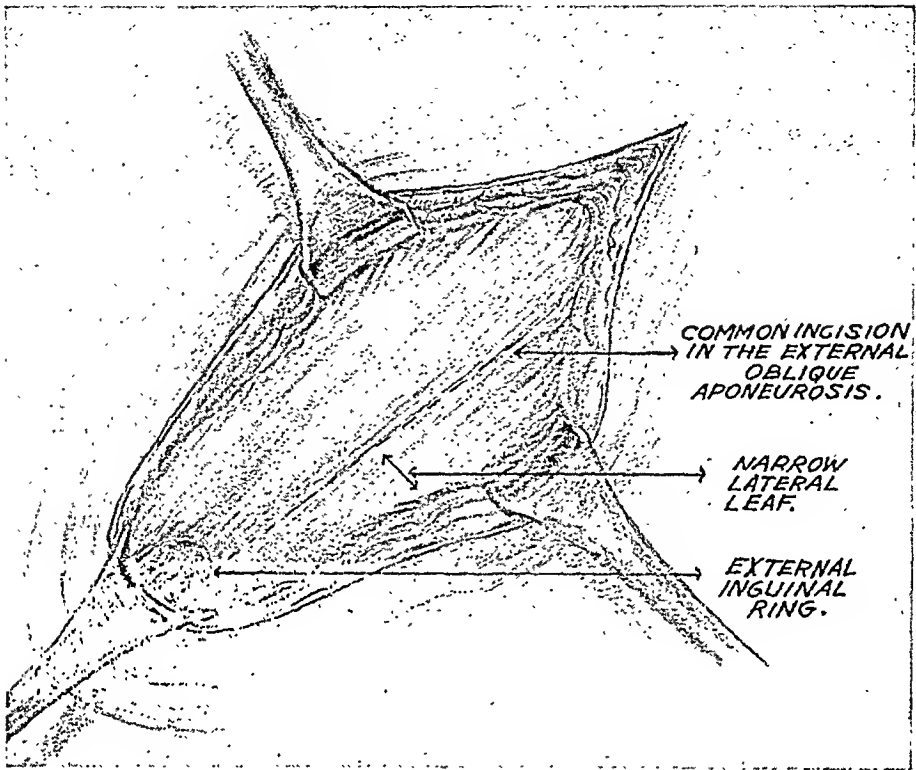


FIG. 6.—Usual incision in external oblique aponeurosis.

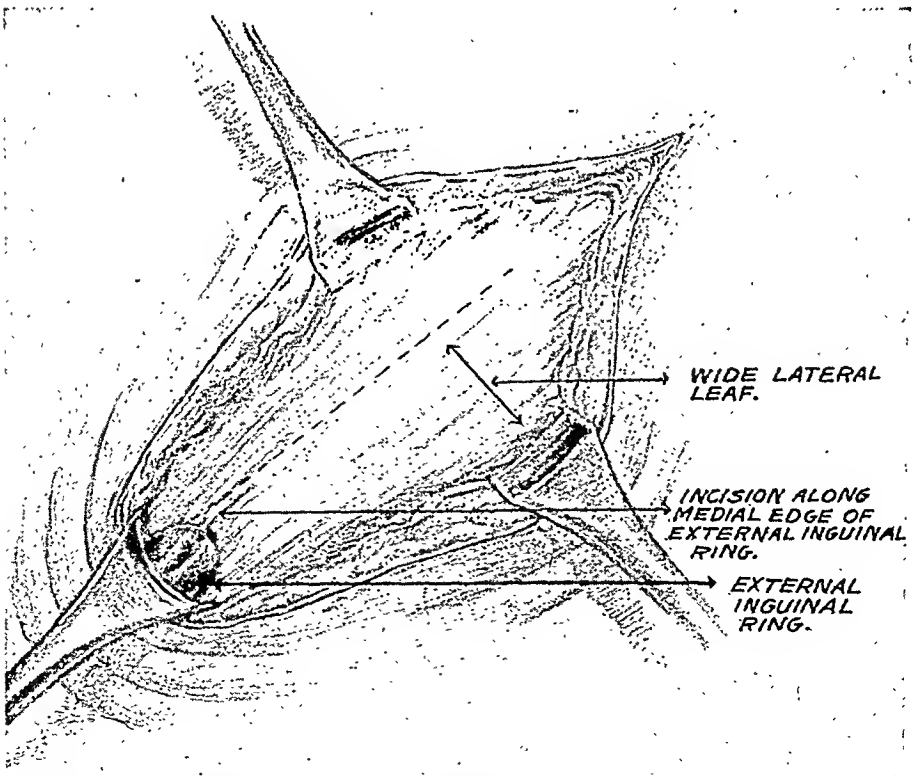


FIG. 7.—Medial incision in external oblique aponeurosis allowing adequate structures for repair without tension.

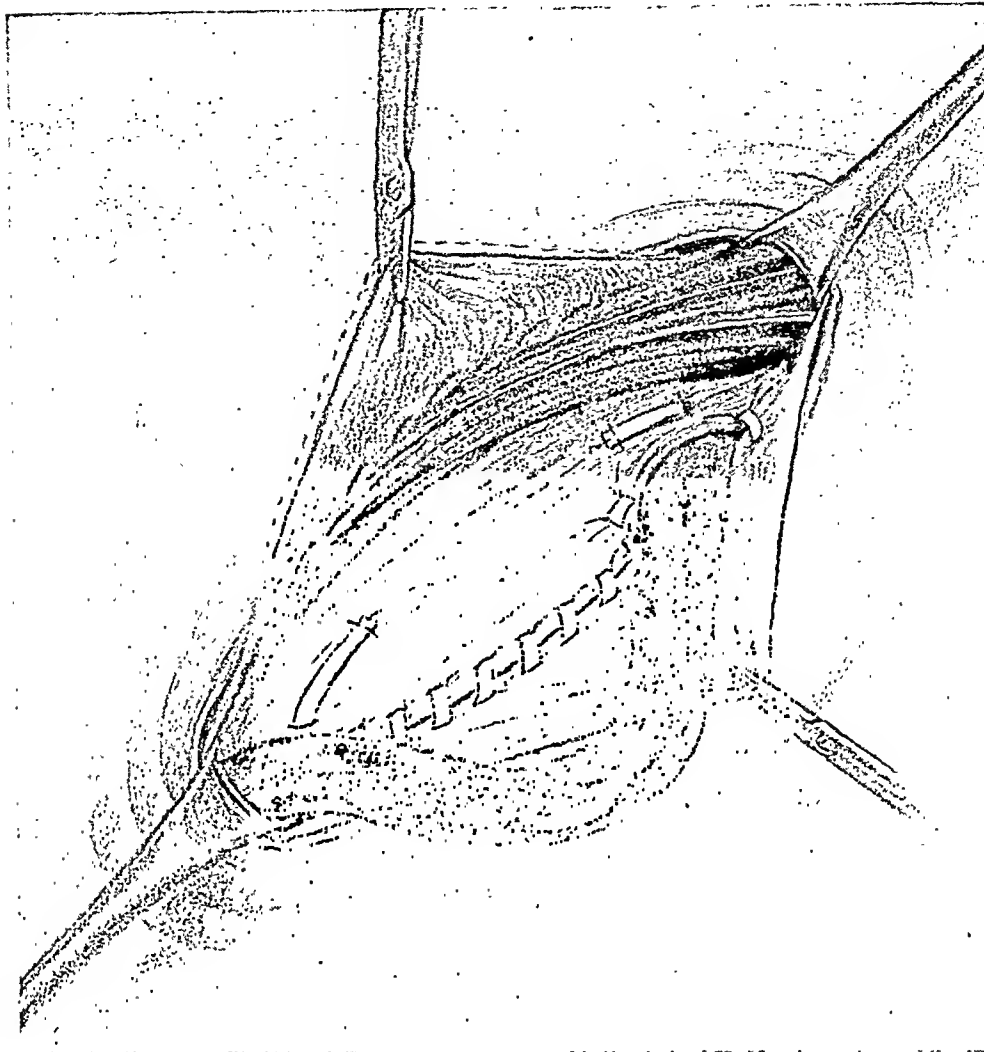


FIG. 8A.—Simple repair with fascia (placement of fascia).

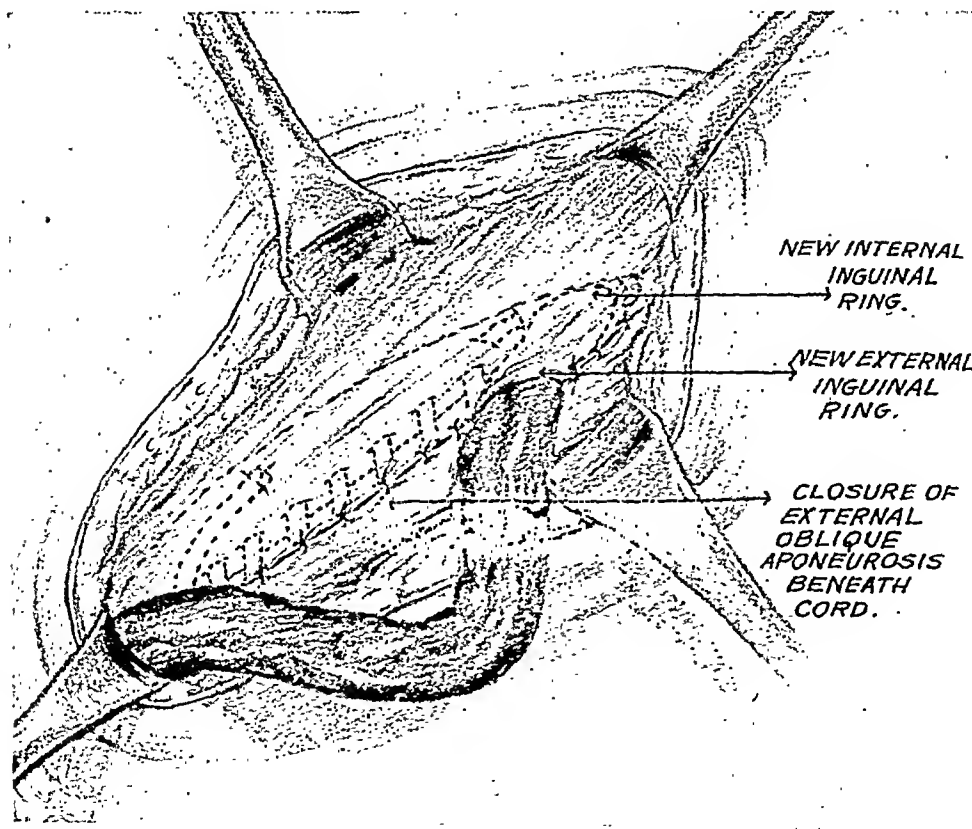


FIG. 8B.—Location of cord following repair. (A second layer of fascia may be placed in the edges of the external oblique aponeurosis.)

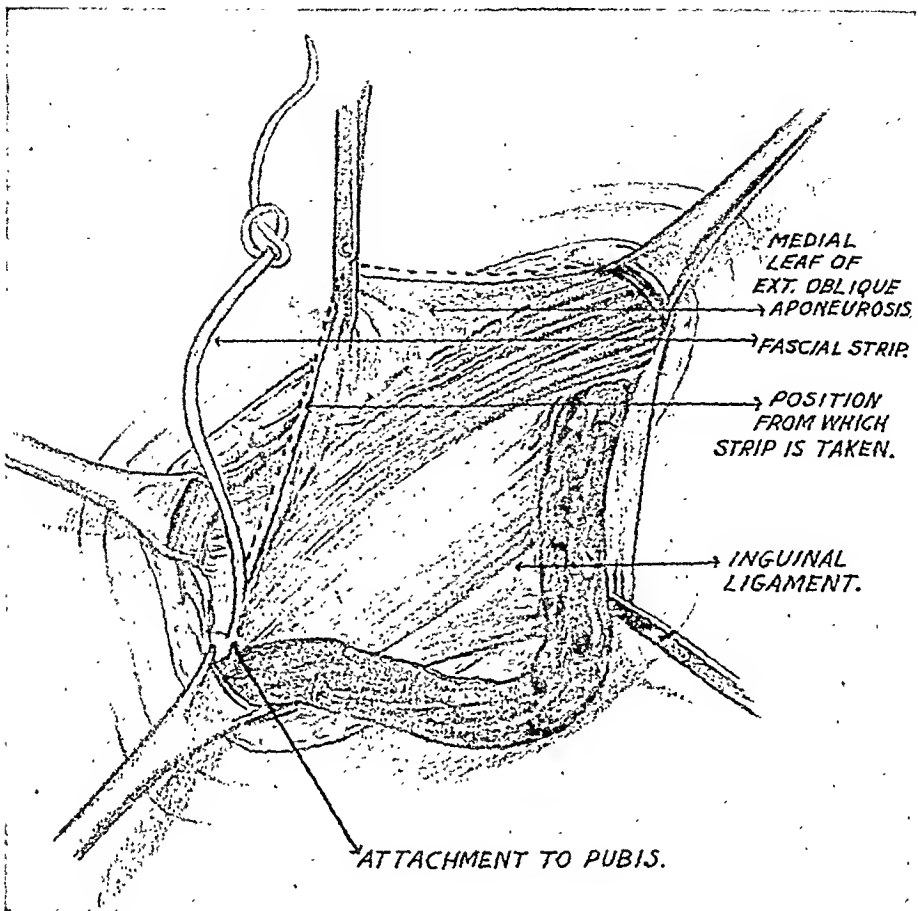


FIG. 9A.—Fascial strip from medial leaf of external oblique aponeurosis.

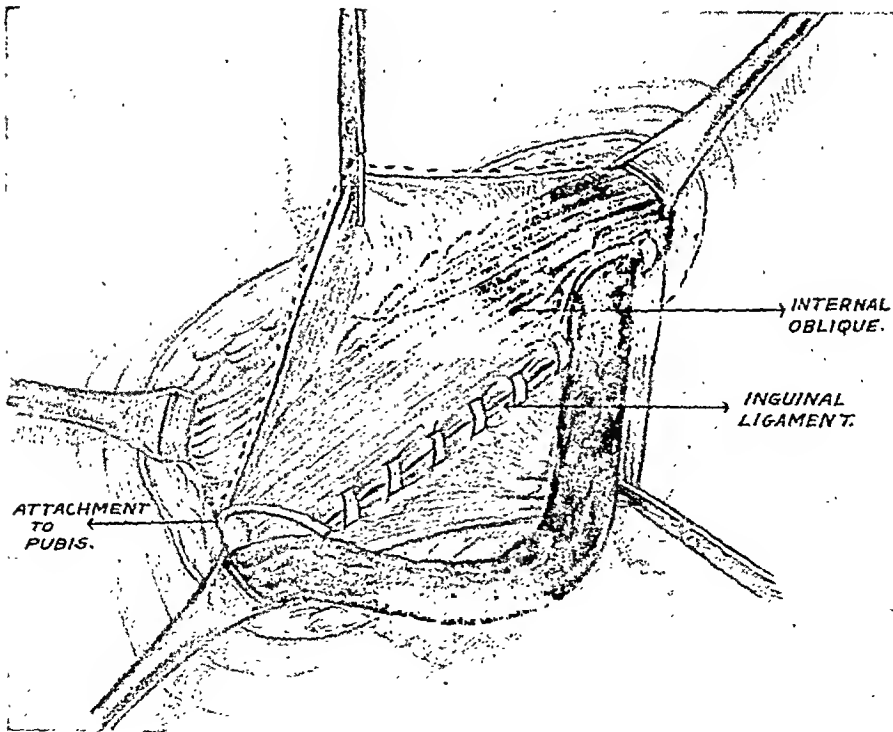


FIG. 9B.—Fascial strip sutured in place.

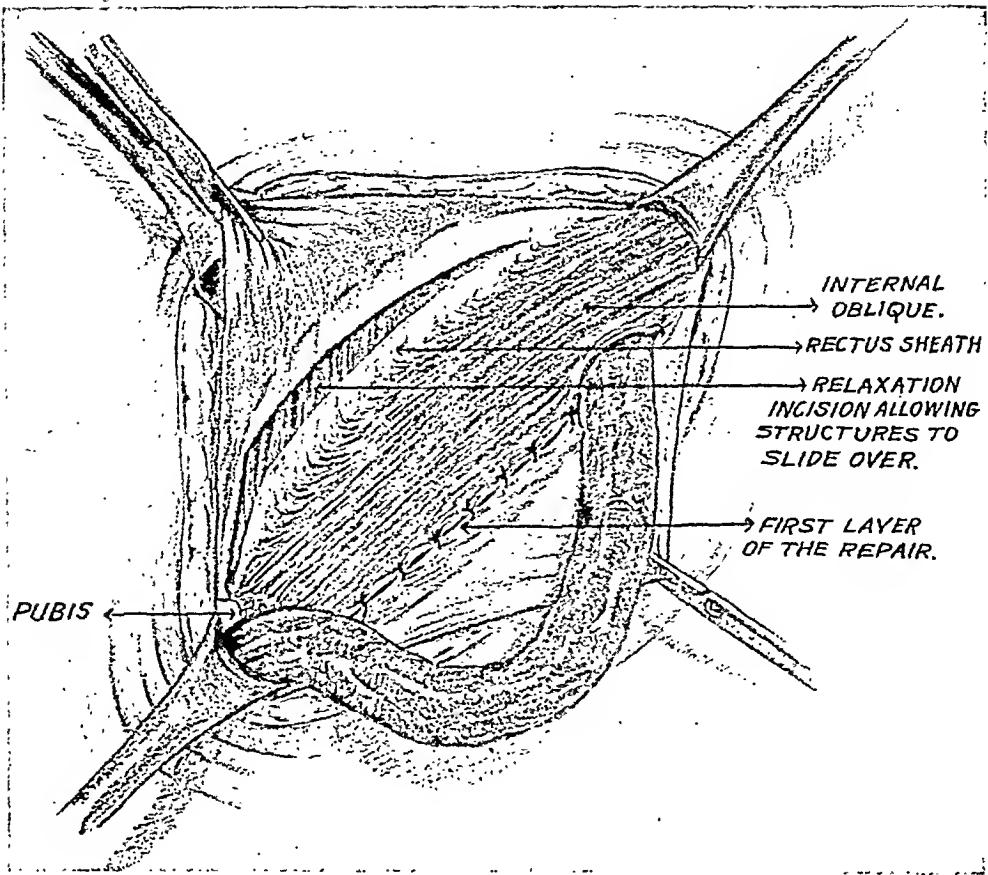


FIG. 10.—Relaxing incision.

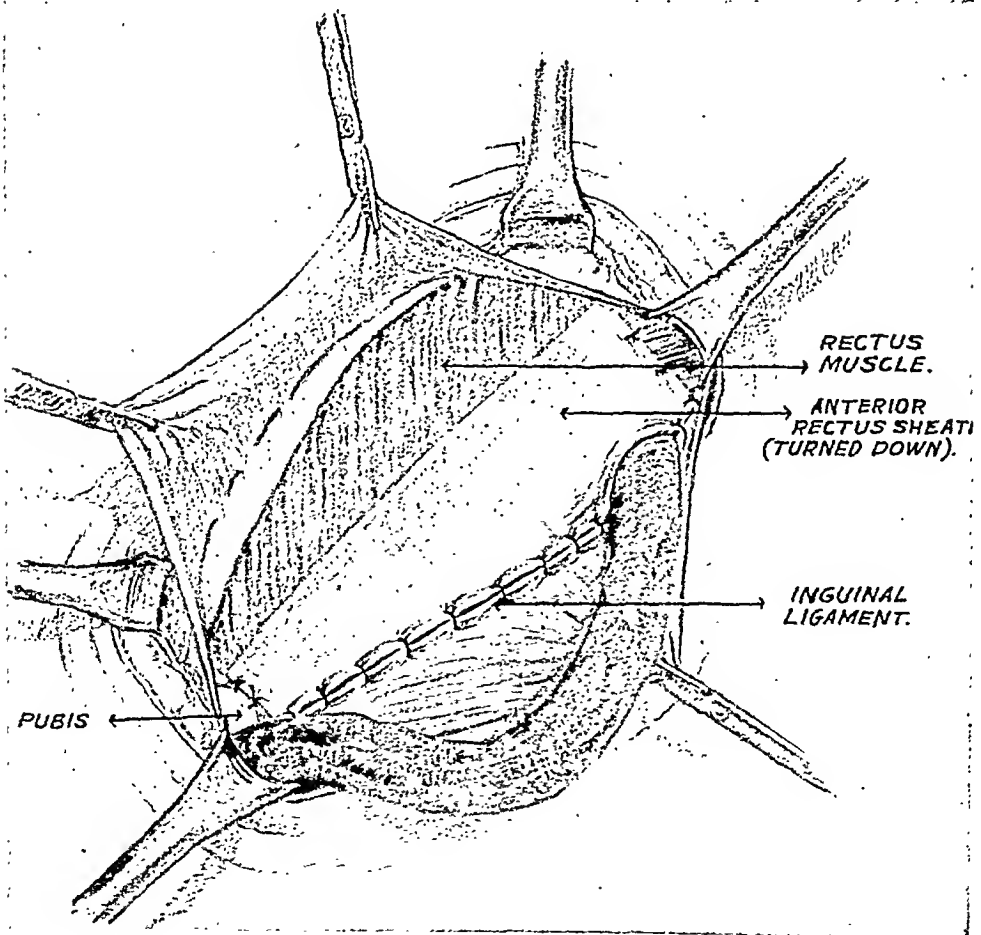


FIG. 11.—Use of cut rectus sheath.

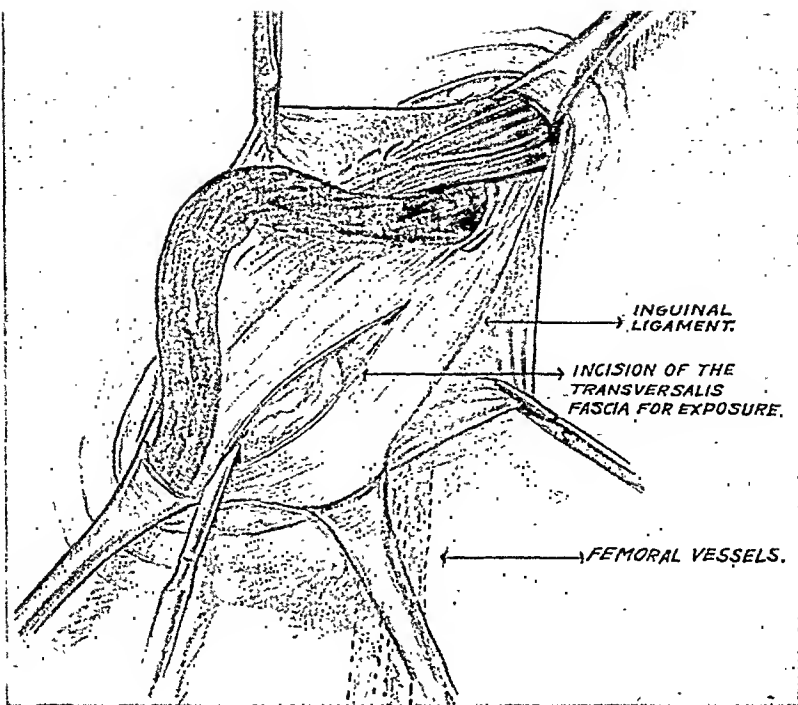


FIG. 12A.—The exposure.  
Suture of inguinal ligament to the lacunar ligament and the Cooper's ligament for combination direct and femoral hernia (repair for hernia as in Fig. 4.).

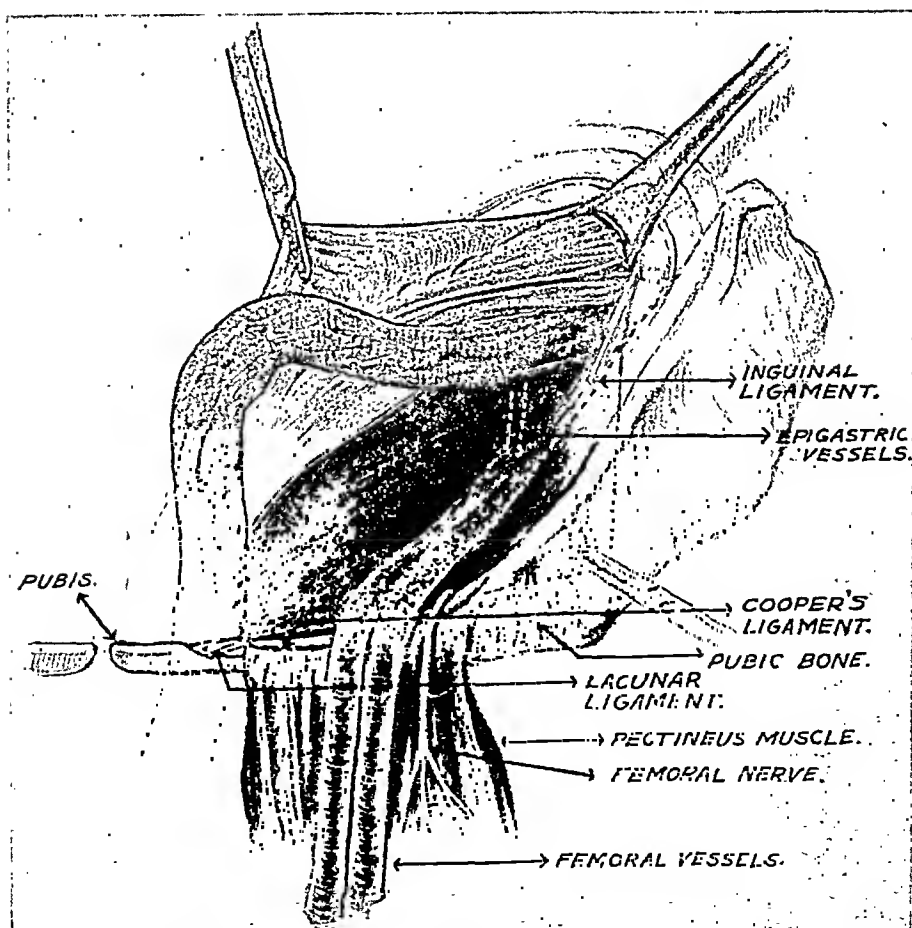


FIG. 12B.—Anterior view as above (with ligament removed for diagrammatic purposes).

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In Figures 6 to 14 are shown the various operative procedures used in this series, with the exception of our usual type of primary hernia repair, which is illustrated in another article. Combinations of the procedures shown may also be used as indicated. This has been particularly true in

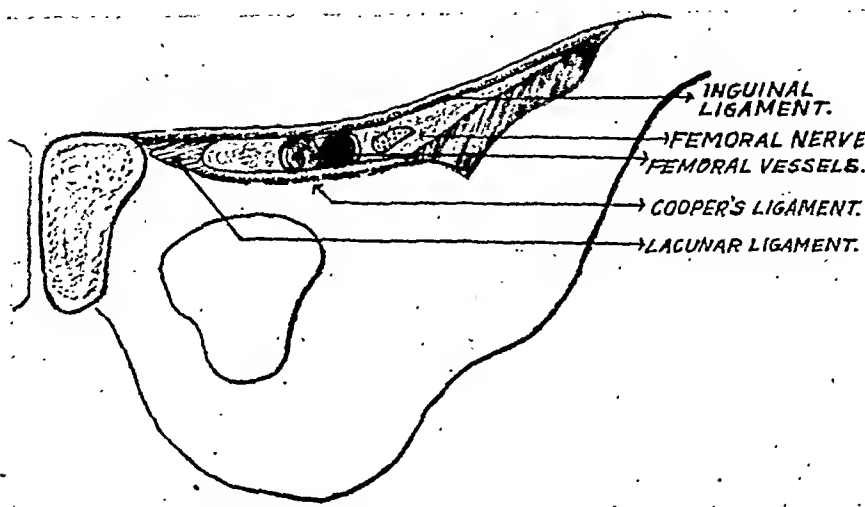


FIG. 12C.—Inferior view (before repair).

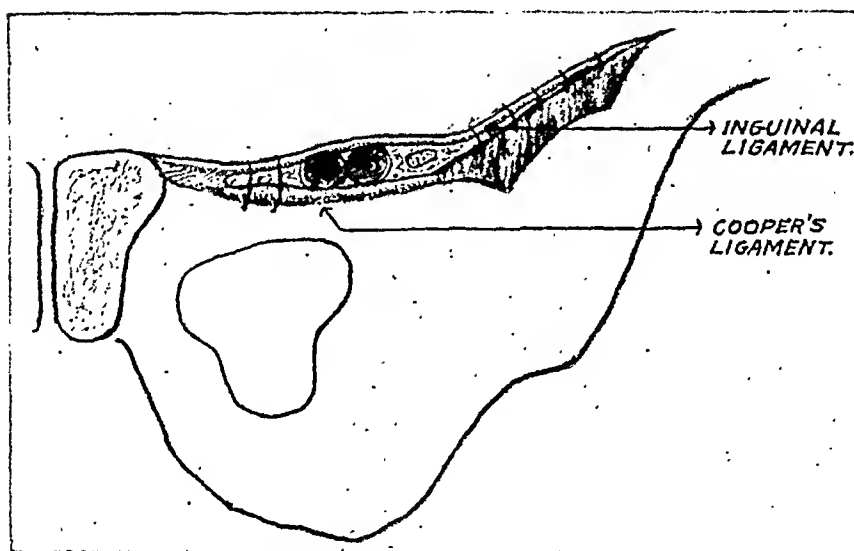


FIG. 12D.—Tightening of inguinal ligament and closure of femoral canal.

the use of the relaxation incision, as shown in Figure 9. Figures 6 and 7 show a point in the technic that we feel to be quite an aid in the carrying out of satisfactory repairs. The establishment of a fairly wide and good lateral edge of the external oblique aponeurosis allows the use of the reflexion of the inguinal ligament as mentioned previously, and gives one a fairly large flap of fascial tissue which can be handled easily in further repair.

In a number of recurrent herniae in this series, in which the primary repair had been done many years ago, almost virgin structures were encountered. In almost all instances these are of the recurrent indirect type.



When such is the case and these fascial structures can be separated easily layer by layer, and these structures appear to be composed of good firm tissue, a primary type of repair is carried out. If the separation by layers is readily accomplished but the structures are of poor quality, they are usually reinforced with fascia from the medial edge of the external oblique aponeurosis (Fig. 8) or from the fascia lata (Fig. 9). We feel that the use of autogenous fascia is very important in the repair of these herniae.

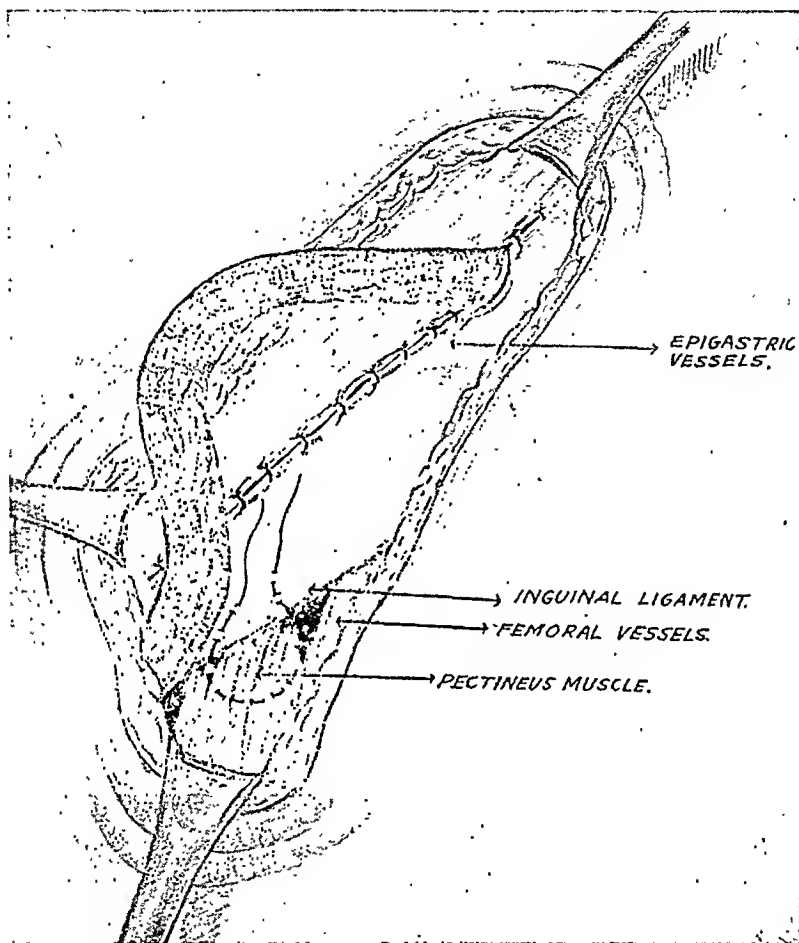


FIG. 12E.—Femoral closure may be reinforced from below.

The relaxation incision of the rectus sheath with or without a sliding over of the anterior rectus sheath, as described by Farr and Rienhoff (Fig. 10), is of considerable importance. The presence of scar tissue and the contraction of tissues as a result of the previous operation or operations tends to cause delayed healing and to increase the tension on the tissues. The relaxation incision allows the use of better structures and releases tension. It does not require repair and, in our experience, has never contributed to recurrence or caused muscle herniation or other local disturbance.

The suture of the inguinal ligament to the lacunar ligament, and to Cooper's ligament and the pectineus muscle fascia, as shown in Figure 12, is

# RECURRENT INGUINAL HERNIA

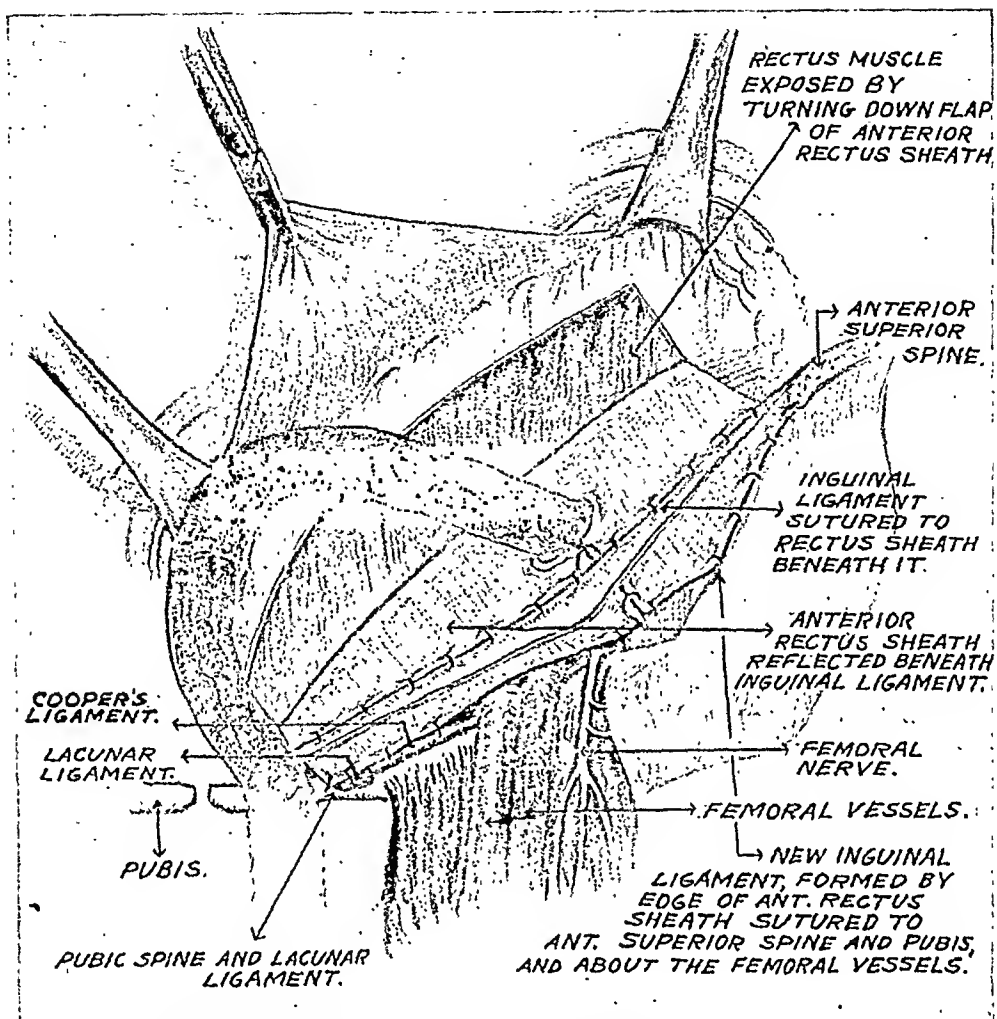


FIG. 13A.—Reconstruction of new inguinal ligament from edge of anterior rectus sheath (for type of recurrence shown in Fig. 5).

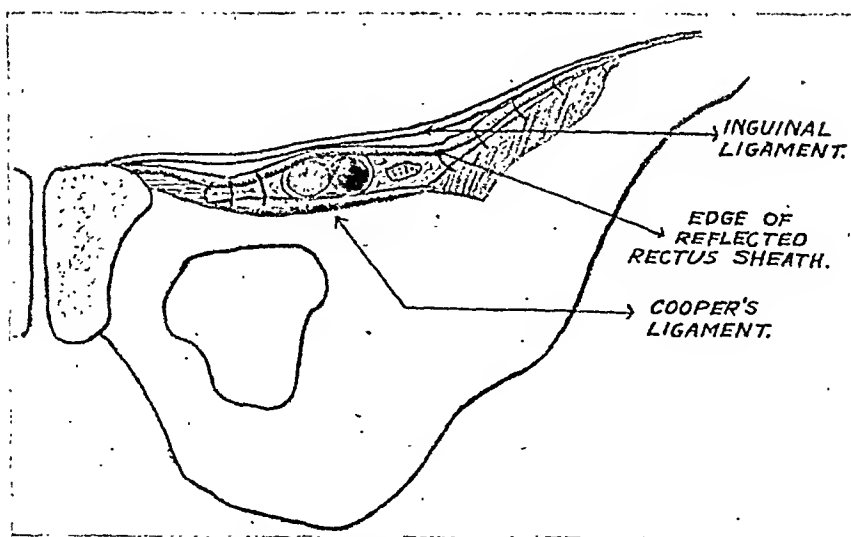


FIG. 13B.—Inferior view showing rectus sheath sutured beneath the inguinal ligament.

used for the recurrent type of hernia shown in Figure 4. This type of repair requires quite a bit more dissection and is a combination of inguinal and femoral hernia repair. A strip of fascia lata may be required to reinforce the direct area, but if used should be placed carefully so that no tension is put on the shelving portion of the lacunar ligament and Cooper's ligament.

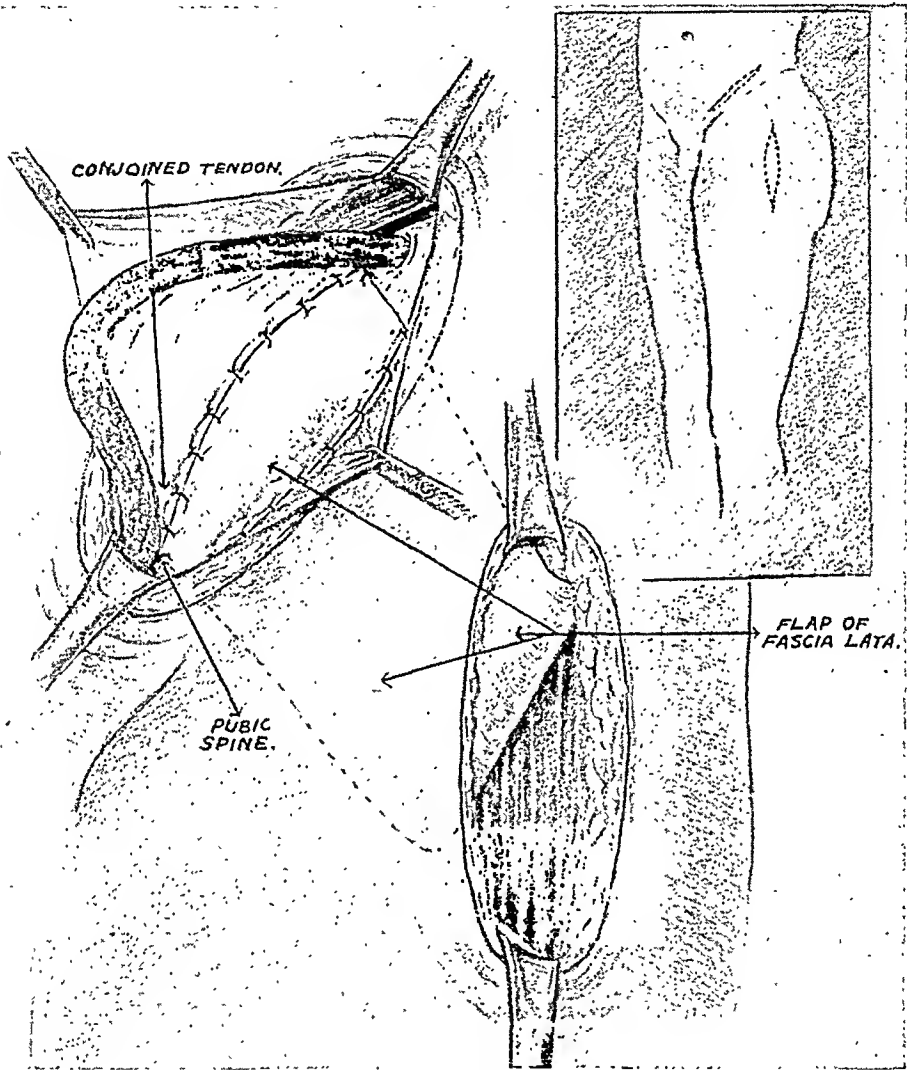


FIG. 14.—Wangensteen fascial flap repair.

The reconstruction of a new inguinal ligament from the cut-edge of the anterior rectus sheath (Fig. 13), has been used by one of us in three instances, with good results. In this procedure an adequate flap is turned down from the anterior rectus sheath. This flap is then carried beneath the stretched out inguinal ligament and is sutured to the pubic spine, the lacunar ligament, Cooper's ligament, about the femoral vessels, respectively, and if desired, or necessary, may be made long enough to be attached to the anterior superior spine. This would then create a new adherent inguinal ligament. The defect in the anterior rectus sheath is covered when the external oblique

aponeurosis is brought together and creates no weakness. We have not been able to find in the literature the description of a similar procedure. Halsted has described a rectus sheath flap operation in which the rectus sheath is sutured to the inguinal ligament, but this is not as described in Figure 13 in this paper. McVay-Lotheissen, and Swenson and Harkins, have described a procedure in which the conjoined tendon is sutured to Cooper's ligament. This is somewhat similar to the procedure described above. This repair we have used in the type of hernia shown in Figure 5, in which the entire inguinal ligament is loosened and frayed-out, and is of no value for use in the repair. It seems likely that this procedure could be used for other recurrences also, such as that shown in Figure 4.

The Wangensteen repair, using a turned-up flap of fascia lata, as shown in Figure 14, we have usually reserved for correction of this type of hernia (shown in Figure 5) until the repair described in the preceding paragraph was started. The Wangensteen repair was used in four of our cases, with good results. It involves a great deal of dissection; including dissection on the thigh, and there is usually some local bulging and slight deformity of the thigh for a period of time. It was for this reason that the previously described operation (Fig. 15) was devised. The repair, using the Wangensteen procedure, however, is undoubtedly excellent.

There has been no mortality in this series of cases.

#### SUMMARY

1. A review of the statistics and causes of primary and secondary recurrences of inguinal hernia is given.
2. The basic types of recurrences in this series are illustrated and discussed.
3. The various repairs in this series are illustrated and discussed, and the repairs suitable for the various types of recurrences are offered for consideration.
4. One hundred twenty-six cases, with 129 operations are analyzed. There were four secondary recurrences, giving a secondary recurrence rate of 3.1%. There was no mortality.
5. The reconstruction of a new inguinal ligament using the edge of an anterior rectus sheath flap is described and illustrated.

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# THE PRESENT STATUS OF THE INJECTION TREATMENT OF HERNIA

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THE REVIVAL OF INTEREST in the injection treatment of hernia so apparent about ten years ago in many parts of the country seems to have subsided to a great degree. In the last five years I have seen no reports from responsible clinics advocating this form of treatment. In the previous five years, however, we can all recall the favorable reports of the success of this method which emanated from various clinics throughout the country. For example—Watson in his textbook on Hernia, published in 1938, quotes Rice, who collected from the literature 6550 cases treated by injection with 92.6 per cent cures. Other figures quoted by Watson<sup>1</sup> are: Larson 93.5 per cent cures; Wyss 91 per cent cures; Quillan 96 per cent, and Bratrud who states the recurrence rate following operation is 17 per cent and only 4 per cent following injection. These were certainly very glowing reports and along with many other similar figures were responsible for arousing such great interest in this form of treatment. In the light of all these favorable reports, it was felt that we, at the Ruptured and Crippled Hospital, should learn something about this treatment, and, consequently, in 1934, after being taught the method by one of its ardent protagonists, a group of 66 patients with 92 herniae were treated. The results of this study were published by Burdick and Coley<sup>2</sup> in 1937. They reported at that time 56 patients who were followed, and only 11 showed no definite evidence of recurrences and nine of these 11 were still wearing trusses. In a later check-up on these 11 patients we have found that not one was cured. These findings discouraged us in the use of the injection method.

This method, in our opinion, not only does not cure any hernia but actually complicates the condition to such a degree that any subsequent attempt at surgical repair lessens the patient's chance of a cure. Rice,<sup>3</sup> who in previous years had been one of the advocates of this method of treatment, seems to have lost some of his enthusiasm. In a personal communication this year he states: "I am now doing very little injection treatment of hernia though I still believe it has a narrow field of usefulness. I now use it only in slender individuals, and in these I believe good results can still be obtained." He states further: "I cannot give you my percentage of recurrences because I have not definitely checked them but it is my impression that if one uses it in the very thin people, the recurrence rate is extremely low."

The chief reason, however, in making this report is not to condemn the injection method for its failure to cure herniae but rather to condemn the dangerous statement that it is "all right to try the injection method as no harm is likely to come of it and we can always operate." Our interest in this subject was revived in the past few years by the increasing number of

patients coming to the hospital for operation who had previously been injected. Practically every one of these cases presented a difficult problem. The tissues in these previously injected cases showed marked fibrotic changes and had lost all their resiliency. In most of them a semicartilaginous ring of tissue was found about the internal ring. This firm, nonresilient ring of tissue was, in several cases, the cause of strangulation. The following case represents such a complication:

**Case Report.**—Patient E. M., emergency operation at Bellevue Hospital. Through the usual incision the external oblique was exposed. It was found to have a cadaveric appearance, and to be quite adherent to the internal oblique. On incision, a dark red, distended sac was exposed. This was incised and found to contain about one ounce of dark bloody fluid. The intestine was very dark and the blood supply was interfered with for a distance of some three inches. On relieving the constriction and applying hot towels, the intestine proved to be viable. The sac, which was about four centimeters in length, was separated. There were no adhesions within it but it was intimately adherent to the cord. The internal ring was very much infiltrated and had to be incised laterally before the intestine could be reduced. The opening therein admitted two fingers; apparently there were firm adhesions throughout the rest of the posterior wall. The cord was excised, the internal oblique and transversalis sutured to Poupart's ligament, and the external oblique closed in the usual manner. Apparently, this strangulation occurred because of the nonresiliency of the internal ring due to the infiltration from the injections.

Lest the question be raised that the proper technic might not have been used or the patient not injected over a sufficiently long period of time, I would like to mention a case operated upon this past year by Doctor Burdick and myself. This patient is a son-in-law of one of the most experienced advocates of this form of treatment in New York City, and over a period of years had had innumerable injections, with no success. This patient, C. C., age 48, was admitted to the Ruptured and Crippled Hospital on May 24, 1943. At operation, the external oblique aponeurosis and conjoined tendon were found to be very fibrotic and adherent. With great difficulty the direct sac was freed and the usual repair, using cotton, was performed. The patient made an uneventful convalescence. He was examined postoperatively at regular intervals. He did not return to work until eight weeks from the date of operation. Four months after his operation he was found to have a recurrence on his right side and the left side gave evidence of great weakness. We feel that this recurrence can definitely be ascribed to his previous injections. The tissues in this patient were in such a fibrotic condition as a result of his injections as to make it impossible for normal healing to take place. It is quite true that recurrences do occur even in patients who have not been injected, but once a patient has been injected the reaction set up in the tissues increases the possibility of a recurrence to such an extent, and according to our previously reported statistics with no hope of cure, we feel it is fallacious to say "that it is all right to inject a hernia as it can always be operated upon later."

During the past two years we have had the opportunity of operating upon a group of 18 patients who had previously had their herniae injected.

Half of this group were found to have indirect herniae, the remainder were direct herniae. Every operation was considerably more difficult than it would have been had the patient not been previously injected. We have not been able to follow all these cases since operation, but of those we have followed we have already found four recurrences. Even granting that all the remaining cases are cured it leaves us with a 22 per cent recurrence rate, which is much too high when one considers that all these patients had simple herniae to begin with. The injections these patients were subjected to accomplished nothing except to increase the difficulties of the operation and definitely increase the recurrence rate following operation.

In the light of our experience upon operating upon these patients, we have come to the definite conclusion that the injection treatment has no place in the treatment of hernia and its use should be condemned.

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# CANCER OF THE FACE

## A CLINICAL AND STATISTICAL STUDY OF 1062 CASES

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MOST PUBLICATIONS on the subject of facial skin cancer recommend radiation therapy, while the importance of surgical treatment is not properly emphasized. The indications for surgical treatment are not clear-cut, and the management of the residual lymph nodes is obscured by the controversy between radiation and surgical dissection.

The purpose of this paper is to summarize the present conception of the subject and to outline the treatment of skin cancer of the face as practiced by the members of the staff of the New York Skin and Cancer Unit of the Post-Graduate Hospital. The study comprises 1062 cases of facial cancer examined and treated during the years 1929-1938.

### FREQUENCY OF SKIN CANCER

The ten-year mortality statistics (1931-1940) of the U. S. Registry<sup>1</sup> shows the appalling number of 33,665 deaths from skin cancer. This figure includes the more malignant varieties of skin lesions, the sarcomata and malignant melanomata which are more difficult to control. With a population composed of more older people today, the incidence of skin cancer will increase, therefore, the subject should become more important. It is estimated that there are several hundred thousand cases of facial cancer in the United States, and the death rate has not improved in the last 15 years.

At the Tumor Clinic of the New York Post-Graduate Medical School and Hospital during the ten-year period of 1929-1938, out of 3,303 lesions of the head, 2,252 cases were diagnosed as malignant tumors. This paper will include only the 1,062 carcinomata of the skin of the face because the cancer of the lip,<sup>2</sup> cancer of the tongue,<sup>3</sup> cancer of the extremities,<sup>4</sup> and malignant melanoma<sup>5</sup> have previously been reported. Further studies on cancer of the mouth, cheek and parotid gland and on the sarcomata are now being prepared and will be presented elsewhere.

### ETIOLOGY OF CANCER OF THE FACE

Although no single factor can be established as the cause of skin cancer the literature mentions: contact with coal tar products, undue exposure to actinic rays or to inclemencies of the weather or to radioactive substances, *etc.*, as contributory factors in predisposed individuals. It is also stated that precancerous dermatoses, hyperkeratosis (senile, arsenical) and xeroderma pigmentosum, unless protected from actinic rays, will degenerate into cancer. In this study, 18 per cent of the patients showed hyperkeratosis as a definite precancerous condition.

Occasionally, malignant degeneration has occurred in neglected, long-standing sebaceous cysts, especially in the older age-group. It was also found in patients with radiodermatitis.

Cancer is less likely to develop in hairy or bearded areas. Where shaving cleanses the skin and the configuration of the face permits thorough washing, malignant lesions are infrequent. Skin cancer is more likely to develop in the creases of the nasal and paranasal areas which are rather neglected during the routine face washing. It is found mostly in areas with abundant sebaceous glands, where the excreted sebaceous material is left on the skin relatively undisturbed by cleansing. Whether the sebaceous secretion serves as a solvent to cancerogenic substances or whether, on such areas, fermentation of the sudorific and sebaceous glands' secretion may be a contributing factor in the development of skin cancer, is not known. Uncleanliness, therefore, is considered a factor in chronic irritation and is productive of cancerogenic agents, whether it is caused by continued exposure to industrial hazards or by accidental exposure in everyday life. This may be a reason for the predominance of facial cancer in the poorer classes with defective hygiene.

#### CLASSIFICATION OF SKIN CANCER

Clinically we have found the following subdivision adequate: 1. Basal cell carcinoma. 2. Squamous cell carcinoma. 3. Mixed baso-squamous carcinoma. Further subdivision of the basal cell carcinoma into types, such as solid, cystic and pigmented, is omitted, as it has no therapeutic importance. Special note, however, is made of the infiltrative type of squamous cell carcinoma which is more extensively removed and is more strictly followed-up because of the possible development of regional metastasis.

Changes of basal cell carcinoma to the more malignant mixed baso-squamous cell carcinoma were rarely observed and those seen were among cases of long standing lesions frequently receiving insufficient radiation.

#### AGE DISTRIBUTION

Our youngest patient was a boy of 13, with xeroderma pigmentosum of the face on which multiple squamous and basal cell carcinoma has periodically developed. A typical basal cell carcinoma on the right parotid region was observed on a girl of 19. The oldest patient on record was a 93-year-old male with multiple basal cell carcinoma of the face. The younger group with "calcifying epithelioma" at the age of 1-20 is not included in this study as the condition is considered benign.

TABLE I

#### AGE AND SEX DISTRIBUTION

Years of Age	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
Basal cell.....	2	8	28	78	117	164	81	17	3
Squamous.....	1	1	4	12	14	33	26	6	..
Mixed.....	..	..	1	9	7	3	6	2	..

Basal cell carcinoma is most frequently observed after the age of 40

and squamous cell carcinoma after 50 years of age. Males predominated (64 per cent) over females (36 per cent), approximately 2 : 1.

There were 12 cases (1.2 per cent) under 30 (eight males, four females) of which ten were basal cell carcinoma (three on the cheeks, three on the eyelids, three on the nose, one in the parotid region) and two squamous (one on the nose and one on the lip). Both squamous lesions were observed in males.

TABLE II  
LOCATION

	Basal	Squamous	Mixed
Forehead.....	42	8	..
Temples.....	61	12	1
Orbital region.....	79	7	7
Nose.....	187	18	5
Cheek.....	137	25	13
Nasolabial fold.....	60	8	..
Parotid region.....	10	3	2
Lip (vermillion border not included) .....	14	2	..
Chin.....	8	3	..
Ears (behind the ear).....	14(10)	29(1)	1
Mastoid region.....	15	1	2
	<hr/> 427	<hr/> 116	<hr/> 32

#### ANATOMIC DISTRIBUTION

Facial cancer greatly outnumbers other skin cancers. The distribution of the lesions in our cases showed about one-third of the basal cell carcinomas on the nose, usually situated on the bridge, dorsum, base, spreading over the nostrils. Less than 10 per cent were found on the exact midline. The nasolabial folds were thickly involved constituting the smallest, most condensed area around the nose. Frequent sites were the temporal regions, the neighborhood of the lower eyelid, and the area of both inner canthi. They were rarely observed below the line connecting the lobe of the ear with the mouth.

Squamous cell carcinoma predominates on the ear, especially the upper part of the helix. Next to the nose and forehead, the temples and nasolabial folds were involved most frequently (the lesions on the vermillion border of the lips being omitted).

Mixed baso-squamous lesions were found mostly at the temporal, zygomatic, preauricular and nasal regions.

An attempt was made to check the "dyontogenic" origin of these skin tumors. Correlating occurrences of lesions with the embryonic inclusion lines, failed to reveal any direct relationships. Therefore, the statement made by previous authors<sup>6, 7</sup> that basal cell carcinomata develop on the face at the inclusion lines could not be confirmed.

*Duration and Delay of Consultation.*—Table III shows the duration of lesions before consultation for treatment.

Basal cell carcinoma, being generally a very slowly growing tumor, does not alarm the patient and consultation is often delayed for years. The quicker growth of the squamous variety explains the earlier consultation.

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To prevent delay of diagnosis, the more frequent use of biopsies are recommended. The need of public education and the distribution of more information do not need to be emphasized as vital factors for earlier treatment.

TABLE III  
DURATION OF LESIONS BEFORE CONSULTATION

Period	Mos.	3 Mos.	6 Mos.	9 Mos.	1 Yr.	2 Yrs.	3 Yrs.	Longer
Basal.....	5	40	62	21	87	69	90	70
Squamous.....	8	34	11	7	13	4	6	2
Mixed.....	..	2	8	1	10	3	6	3

### SIZE OF THE LESIONS

The size of the lesion was in direct proportion to the delay in consultation and it varied from 2 mm. to 11 cm. in diameters. Only one-fourth of our patients applied for treatment when the lesions were less than 1 cm.; one-fourth waited until it was over 2 cm. in diameter, and half had lesions between 1-2 cm.

### MODES OF SPREAD AND LYMPH NODE METASTASIS

Skin cancer of the face spreads by direct extension. Basal cell carcinoma practically never metastatizes; in two instances when it was found in regional lymph nodes we were dealing with extensive lesions, and direct invasions rather than metastases had to be considered. Among squamous cell lesions of the face metastases were rare. The impression prevails that the deeply infiltrating squamous lesions breaking through subcutaneous fascia, involving the underlying facial muscles should be observed closely for regional lymph node metastases.

Squamous cell carcinoma of the ear exposed to frequent and repeated trauma involves the regional lymph nodes frequently, similarly to the squamous cell lesions of the vermillion border of the lips. This observation corresponds to that found in melanomata of the ears and extremities<sup>5</sup> which metastasize more readily if traumatized.

Of the 69 surgically treated cases of squamous cell carcinoma of the face followed over a five-year period, we had only three cases of regional lymph node involvement. One lesion was located at the preauricular region and developed metastasis in three months after receiving radium treatment and two others treated with radiation with advanced lesions of the nose. Cervical lymph node dissection was performed six times for squamous cell carcinoma of the face. Only in one specimen was there lymph node involvement which was clinically evident, the original lesion being situated on the nose. A patient developed cervical lymph node metastasis after a long-standing squamous cell carcinoma of the nose developed in a roentgen ray burn. According to our observation, squamous cell carcinoma of the face (unlike ear and lip lesions) rarely forms metastases in the regional lymph nodes, but they may do so if neglected or traumatized.

### SYMPTOMATOLOGY

The most frequent "early" sign of a facial skin cancer was the formation

of a "scaly spot" or a small painless "pimple" which persisted in spite of the application of home and drug store remedies. These lesions increased in size, with a tendency to bleed or ooze when the scab was picked off and showing no tendency to heal.

*Physical Findings:* (1) *Basal cell carcinomas* are round or oval, or polyhedral. At first they are waxy, elevated, indurated nodules, becoming "pearly" on the border and crusted in the center as they extend, with rolled, undulant edge. They may ulcerate or remain nodular, elevated or papillary, while slowly growing and infiltrating into the surrounding skin rather than the underlying tissue. Some tumors are solid or cystic, others superficially expansive, showing epithelization in the center (rodent ulcer). The majority show a scab-covered ulceration. Removal of the scab reveals a grayish, vitreous base, with some oozing or bleeding. Some lesions of long-standing may show extensive involvement, deformity and local destruction, particularly those involving the nose, eye or ear.

(2) *Squamous cell carcinoma* shows a more rapid growth than basal cell carcinoma. The lesion is a spherical, elevated, indurated, scab-covered area, beginning as a well defined, firm, warty nodule which ulcerates in the center as it grows larger. Until ulceration is delayed the lesion is elevated, smooth, spherical. Irregularity was seen rather in the deep, involving variety. The spherical, elevated, superficial type is the most frequently observed. It may be portrayed as a deep, dirty, ragged, irregular, indurated ulceration.

(3) *Mixed or baso-squamous carcinoma* is rarely diagnosed clinically. It appears as a rather irregular, scab-covered, penetrating ulcerated lesion with infiltrative tendencies. It is usually of long duration. It comprises from 6 to 12 per cent of cancer of the face (McKee,<sup>7</sup> 12.6 per cent). From a practical point of view, its treatment is like that of squamous cell carcinoma.

(4) *Multiple Lesions.*—The low percentage of multiple lesions does not confirm the clinical impression which is inclined to be much higher. They were present in 36 cases (multiple basal cell, 25; basal and squamous cell, 3; multiple squamous, 3; and 5 basal and squamous, with mixed carcinoma). One woman with facial cancer also had cancer of the breast. Keratosis was found in association with cancer in a great majority of patients over 60 years of age (18 per cent of the total).

*Recurrence.*—At the time of application 20 per cent of our cases had recurrent lesions, having received previous treatment elsewhere. Table IV shows known previous treatments in recurrent lesions.

#### PROGNOSIS

All three types of facial cancer are progressive. Authenticated, spontaneous healing was not observed. As the disease slowly progresses, producing local destruction of tissues, ulceration with secondary infection takes place, which may be followed by oozing, bleeding or hemorrhage due to

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erosions of vessels. Basal cell carcinoma is generally a slow-growing tumor lasting for years; though in about 3 per cent it presents more active growth. Squamous cell and mixed, basal squamous carcinoma of the face, if neglected, may metastasize into internal organs causing cancerous cachexia and death.

The outlook is very serious when the neglected or mishandled superficial skin cancer involves underlying bone, the paranasal sinuses or the internal ear, or if the tumor breaks through the outer table of the skull, where the spread is greatly enhanced by the venous pools of the spongy structure of the bone.

TABLE IV

	Basal	Squamous	Mixed
Radiation.....	32	12	6
Operative.....	7	3	1
Electric needle*.....	25	5	2
Chemical cautery.....	3	2	..
Actual cautery.....	2	3	..
Silk ties.....	2	..	..
Total.....	71	25	9

\* Considering the large number of early skin cancers treated by the dermatologist and general practitioner by desiccation, its effectiveness may be favorably compared with radiation therapy

### ADVANCED CANCER

The reasons for delayed consultation are interesting. Many patients with advanced and neglected lesions told us that they knew they had cancer, but as they considered it an incurable disease no medical advice was sought. Some cases came only when the advanced lesion had become painful. Others stated that they knew somebody who died of recurrence in spite of treatment. The majority came with the history of inadequate treatment, mainly radiation or timid surgical intervention. Others had lost faith in medical efficiency after the lesion recurred, quoting too dogmatic statements of certain cure made by the attending physician at the time of the previous treatment. The importance of the follow-up examination was not explained to the patient.

Some had been treated conservatively for years by the application of ointments, as the correct diagnosis was not made by the attending "physician." In the advanced cancer cases the surgical use of the high frequency current was found highly beneficial for curative and palliative treatment.<sup>10</sup>

### PROPHYLACTIC TREATMENT

Education of the laity and the profession is advocated for prompt diagnosis and treatment of early lesions, which will eliminate the high death rate by skin cancer, which, in our opinion, should be negligible. The information should include differentiation among types of cancers, emphasizing the relatively benign nature of skin cancer. The laity should be instructed that practically any ulceration, if not healed in three weeks by the customary conservative treatment, needs biopsy, serologic examination and that, generally, they should seek early competent medical advice for skin lesions.

Cleanliness should be advocated, and prevention of undue chronic skin irritations by sun and weather and the contact of cancerogenic agents,

especially among older individuals, should be emphasized. In industry it is the responsibility of the supervising physicians to induce proper hygiene. Treatment of keratotic lesions, preferably by electrodesiccation should be widely practiced.

Some long-standing sebaceous cysts have shown malignant degeneration under the microscope. Usually this lesion is well-encapsulated and after customary excision, when the pathologist reports an early cancer with low activity, additional surgery may not be necessary.

*Differential diagnosis* is not difficult to those familiar with the varieties of skin cancer. When senile keratosis is in the early stage of cancerous degeneration it is often necessary to establish a diagnosis by microscopic examination. A small pigmented basal cell carcinoma may be confused with malignant melanoma.

*Fungus infection*, such as actinomycosis, blastomycosis. *Mycosis fungoides* is diagnosed by culture and biopsy. *Leprosy* and *leishmaniasis* were not observed in our service.

*Syphilitic lesions* are confirmed by dark-field and blood examination. The secondary or tertiary lesions may cause difficulty. Syphilitic lesions, also, may be associated with skin cancer. *Gumma* is rare and suspicion is invoked by the positive serum reaction. *Skin tuberculosis* shows variations. *Lupus vulgaris*, *verrucosus* and *erythematosus* of the skin must be considered, and may cause confusion in diagnosis. Therefore, dermatologists should be called more often for consultation in doubtful lesions.

Frequently keratotic or sebaceous nevi are mistaken for basal cell carcinomata. In such cases the etiology and lack of induration or ulceration are helpful. Skin fibromata and verrucae are usually typical lesions and cause no difficulty in diagnosis. A well-performed biopsy often removes a small lesion or repeated if necessary invariably dispels doubt.

#### ANALYSIS OF MATERIAL

There were 1062 cases available from the records of the Tumor Clinic with the clinical diagnosis of facial cancer, as shown in Table V.

TABLE V

Consultation only.....	119	11%
Far advanced.....	43	4%
Treated by radiation.....	381	35%*
Operated upon.....	519	50%
Primary lesions.....	414	80%
Recurrent lesions.....	105	20%
Plastic reconstructive operations.....	147	28%
Total.....	1062	

\* The proportion of patients referred to radiation has been decreased to less than 10% in recent years on account of having prompt and often better cosmetic result after surgical excisions.

#### TREATMENT

Skin cancer is treated according to its type, location and degree of involvement. At the Tumor Clinic the outlined routine which follows is closely observed.

All lesions of the face are referred to a diagnostic clinic where a tentative diagnosis is made by the attending surgeon in the presence of the pathologist. Unless too obvious, the diagnosis is affirmed by a biopsy, consisting of the excision of 2 x 5 mm. of tissue from the periphery of the lesion, including normal epithelium. The defect is closed by suture or preferably in case of large ulcerating tumors, the base is desiccated or coagulated by the high frequency currents. Smaller lesions are excised as biopsies.

The majority of cases (at present more than 90 per cent) are referred for surgery and only selected cases are advised to have radiation.

*Radiation Therapy.*—Skin cancer generally responds readily to radiation therapy, but it is usually ineffective in cases of cartilage or bone involvement. In our clinic excisions give prompt and often superior cosmetic results, as compared to radiation, weighing the late effect of radiation, which many times resulted in skin atrophy and teleangiectasia. Some excellent late results were seen after radiation therapy from our Roentgenologic Department which, however, left us unconvinced as to its more extensive use. It may be advocated in lesions over soft-parts as an alternative to surgery. Other cases referred for radiation are the patients with inoperable tumors or patients with an uncontrolled systemic disease, or extreme old age with cardiovascular disease.

The effectiveness of expert radiation therapy with well-defined indication is beyond question. It is advocated more expressly when surgery is objected to, or it may be recommended if no properly trained surgeon is available with experience necessary for cancer and reconstructive surgery. The fine linear scar left by the surgeon is preferable to the whitish, depressed radiation atrophy often surrounded by wide areas of teleangiectasis.

*Surgical high frequency currents* are used in smaller superficial lesions, not exceeding 5 mm. in diameter. Desiccation (sparking) is the method of choice, followed by curettage and desiccation, repeated until all neoplastic tissues are removed. The wound is left dry and does not require a dressing, except powdering, until healing is obtained. This occurs in one to three weeks depending on the size of the lesions and the degree of destruction of epithelial tissues.

A word of warning against coagulation should be said here. It causes deeper destruction and slower healing, and is not recommended for inexperienced hands. We have repeatedly seen cases referred to us after the use of high frequency currents with distressing results. The indolent, slowly healing ulceration caused by inexpert technic was frequently mistaken for a recurrence or persistent tumor.

In some skin clinics desiccation is used in the majority of skin cancers, followed by the application of radium. The reason for this procedure is not easy to understand. If desiccation is properly applied and the tumor is destroyed, there is no need for radiation, but if the operator does not feel that the cancer cells were all removed and wants the remnants to be destroyed



by radiation, why did he use desiccation? High frequency currents have been advocated before radiation to reduce the bulk of tumor.

*Surgical excision* is the choice of treatment whenever there are no contraindications. Excision should be in three dimensions—that is, besides length and width it should include sufficient depth to prevent recurrence. Deep excision around large vessels means careful anatomic dissection, removing the covering fascia of vessels and nerves.

*Wide excision* does not mean unnecessary mutilation but it should be guided by the type and extent of the lesion. With a superficial basal cell carcinoma, an excision with a half-centimeter wide health margin down to the underlying fascia will be sufficient. But if the lesion involves the subcutaneous tissues the underlying fascia also may have to be removed, depending on the depth of the underlying fatty subcutaneous tissues.

To obtain vital information as to the radical removal of the lesion in our clinic it is customary for the surgeon to excise the tumor, mark the specimen with silk sutures and make a diagram indicating from where it was excised. The pathologist in the tumor service, on the basis of such information, is able to report the width and depth of uninvolved tissues around tumors and to state whether the cancerous tissue was all excised. This is considered very valuable information, for if the excision line runs close to the tumor reexcision may have to be performed.

We wish to emphasize certain areas on the face where the lesions require unusually thorough eradication to avoid troublesome recurrences. The *first* area is the nasolabial fold close to the ala nasi. Tumors here are apt to penetrate early and involve the superior maxillary bone and antrum and, if recurrent, even by radical surgery, are difficult to control. Tumors of the nose involving the septum and ethmoid cells are rather troublesome and open treatment for a long period is advisable. Extensive involvement of such areas is not always hopeless, however, and occasionally a cure results.<sup>8</sup> Our fatal cases belonged to these groups as we lost five in spite of extensive interventions. From the practical point of view, all skin cancer is treated the same way. The rule of wider excision of squamous cell cancer does not hold in the superficial forms and radical removal of the infiltrating type is the same as in the similar type of basal cell cancer; they both must be adequately excised. In regard to squamous cell and mixed baso-squamous cell lesions, it is unfortunate that no rules at present may be formulated as to which lesion will metastasize; although the clinical impression indicates that trauma favors metastasis. The indications for lymph node dissection were previously discussed. The lack of mortality and morbidity of lymph node dissections for skin cancer in the past 15 years should prompt more intervention in doubtful cases.

*Squamous cell carcinoma of the ear* deserves special study as it is characterized by increased tendency to metastasize to the cervical lymph nodes. Of the 25 carcinomata of the ear, our record shows 20 squamous (80 per cent) and five basal cell lesions (20 per cent). The basal cell lesions all

survived the five-year period (one with persistent tumor is alive after seven years). Among the 20 squamous cell carcinomas, two were far-advanced, and in these only biopsy was performed before radiation was given, without benefit. Eighteen were operated upon, with wide excision, frequently consisting of ablation of the ear followed by lymph node dissection. In six lymph node dissections with palpable cervical lymph nodes, involvement was found twice, and one of these patients survived the five-year period. In the remaining cases lymph node dissections were either refused or not performed on account of early lesions. Of the 20 patients with squamous carcinoma of the ear, seven died of general metastases and four were lost from follow-up, nine being alive and well after five years (45 per cent).

This limited number of cases shows the danger of procrastination in squamous cell cancer of the ear. To improve results, even in cases of nonpalpable lymph nodes, routine cervical lymph node dissection should be recommended, with the exception of early noninfiltrating lesions.

#### TREATMENT OF ADVANCED CANCER

In the more advanced or recurrent lesions we practice extremely wide excision or preferably destruction of the tumor by electrocoagulation. This method has certain advantages. It facilitates the recognition of the coagulated tumor and, by contrasting it with the coagulated normal tissue, more thorough eradication is assured. After the tumor has been thus removed, we practice the excision of the remnant of the coagulated tissues with an adequate healthy margin to prevent recurrence and to eliminate tissues damaged by the current which might complicate wound healing. Such procedures gave us gratifying results and control of advanced and repeatedly recurring cancers after radiation or simple surgical excisions had failed.

In the presence of advanced facial cancer, it may be advisable to discuss with the patient the possibility of a recurrence and the necessity of further treatment and follow-up.

#### ANESTHESIA

Excisions are preferably undertaken under local or block anesthesia. Tumors requiring extensive operations and reconstruction are also preferably operated upon under novocaine block. Spreading of skin cancer by the injection of novocaine into the neighboring tissues was not observed.

Sufficient skill acquired in performing novocaine local and block anesthesia will leave less and less cases of radical operations and regional lymph node dissection for general anesthesia, thus cutting down morbidity and mortality.

#### FOLLOW-UP EXAMINATION

In order to detect early recurrence or small new lesions, a regular follow-up examination is imperative. The follow-up period at intervals of one to four months may be limited to three to five years in cancer of the face, but should preferably be for lifetime at yearly intervals.

Patients kept on our follow-up for many years had the benefits of early and simple treatment in cases of the development of new lesions, or occasional recurrence.

*Recurrent Lesions.*—The high percentage of recurrences (20 per cent) among our cases first examined shows how inadequate is the treatment generally for facial cancer. The recurrences frequently require more extensive operations often followed by reconstruction.

Among our primary-operated lesions there were ten (2 per cent) recurrences. In five rather early cases excision was done in the clinic by the resident. Our attending staff operated upon the other five cases, in which recurrences were noted at the nasal, nasolabial, auricular and orbital regions, with bone involvement.

In several cases more than one operation was necessary. Five patients required two operations within four years; two had three operations within two to three years, and one patient had five operations within three years, with the result of arresting the disease.

Cases with persistent cancer, when the palliative operations consisted of electrosurgery, are not included among recurrent lesions. In such cases the aim is to prolong life and alleviate suffering, regardless of statistical results.

#### RECONSTRUCTION

In infiltrating lesions, large defects result from the wide excision in three dimensions necessitating correction by reconstructive plastic surgery. Such extensive removals, essential in cancer surgery, regardless of the ensuing defect, often constituted a problem for reconstruction, especially if eyelids, nose or ear were involved. Where complete eradication was possible, immediate plastic reconstruction was done.

If the paranasal sinuses alone were involved and eradication even by electrocoagulation was doubtful, the wound was left open for later reconstruction. When monthly biopsies of suspicious areas had been negative for about six months to two years plastic reconstruction was performed. In general, we are definitely not in favor of making an invalid of a man who has had cancer of the face and of watching unduly for recurrences in cases where radical extirpation is feasible.

Plastic reconstruction in 147 cases consisted of Thiersch-Ollier skin graft in 48 cases. Pinch-grafts were made in two cases of large infected defects, full-thickness grafts in 47 cases, and repair by skin flaps in 50 cases. There were two recurrences after orbital and nasal plastic reconstructions were completed.

Large defects in elderly individuals were usually covered by skin grafts. Better cosmetic results with occasional minor complications were obtained by using full-thickness graft from behind the ear, upper eyelid or neck, rarely from abdomen.

In more extensive operations skin flaps were used which were lined by skin graft or double flaps when mucosa of the nose and cheek, or con-

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TABLE VI

ANALYSIS OF RESULTS IN 519 PATIENTS WITH CANCER OF THE FACE OPERATED UPON

Total number of cases operated upon..... 519

## Basal Cell Carcinoma:

Total number of cases operated upon.....	416	80.3%
Operative mortality.....	0	.0%
Died of other disease, no recurrence.....	21	5%
Died of persistent or recurrent disease.....	7*	
Alive with persistent or recurrent disease.....	5	2.9%
No follow-ups.....	85	20.4%
Number of basal cell cancer cases under follow-up, less lost and dying from other causes	310	
Alive and well after five years.....	298	96.1%
Primary { Number of cases followed five years, less those lost and dying from other diseases.....	229	
{ Alive and well after five years.....	227	99.0%
Recurrent { Number of cases followed five years, less those lost and dying from other diseases.....	81	
{ Alive and well after five years.....	71	87.6%

\* Dying one to four years after palliative operation and radiation failed.

## Squamous Cell Carcinoma:

Total number of cases operated upon.....	69	13%
Operative mortality.....	1†	
Died of other diseases, no recurrence.....	8	
Died of persistent or recurrent carcinoma.....	9	
Alive with disease at end of five years.....	0	
No follow-ups.....	17	
Total known cases under follow-up, less lost and dying from other diseases.....	44	
Alive and well at end of five years.....	34	
Number of squamous carcinoma of face follow-up.....	24	
Number of squamous carcinoma of face died of disease.....	3	
Number of squamous carcinoma of face alive and well, five years.....	21	87.5%
Number of squamous carcinoma of ears.....	20	
Number of squamous carcinoma died of disease.....	7	
Number of squamous carcinoma, no follow-up.....	4	
Number of squamous carcinoma of ear well after five years.....	9	45.0%

† Wide excision and lymph node dissection for an extensive recurrent lesion.

## Mixed Baso-squamous Cell Carcinoma:

Number of cases operated upon.....	34	7.5%
Operative mortality.....	0	
Died of other diseases, no recurrence.....	1	
Died of persistent or recurrent disease.....	3	
No follow-ups.....	10	
Number of cases followed five years, less lost and dying from other causes.....	24	
Alive and well after five years.....	21	87.5%

## Ten-year Results:

Operated upon more than ten years ago.....	205
No follow-up.....	73
Died of other diseases without recurrence.....	22
Died of persistent or recurrent carcinoma.....	12
Ten-year follow-up, without recurrence.....	98

	Basal	Squamous	Mixed
Total follow-up.....	88	13	9
Ten-year results.....	84	7	7
Per cent of arrests.....	84%	53.8%	77.7%
Died.....	4	6	2
Primary.....	98%		
Recurrent.....	88%		

junctiva had to be formed. Skin flaps consisted of cheek flaps, fronto-temporal flap, and were obtained from neck or scalp.

In recent years only full-thickness grafts and skin flaps have been used for reconstruction, with better cosmetic results.

#### RESULTS

The analysis of the material from the New York Skin and Cancer Unit of the Post-Graduate Hospital from the period of 1929-1938 inclusive, shows the following figures (Table VI):

The high death rate from intercurrent diseases is comprehensible when dealing with an advanced age-group.

Many of our cases on the follow-up were lost, as we receive our patients from a highly unsettled group of people in New York City, and, besides, many expressed the desire not to be followed-up after various periods.

Seven patients with basal cell carcinoma were found alive but with disease at the end of five years; these all died later. One case of adenocarcinoma of the nose was reported with multiple recurrences and dying of general metastasis two years after palliative electrocoagulation of the cheek and nose.

Among those dying of persistent and recurrent cancer in the ten-year group were four cases of basal cell, six of squamous, and two of mixed carcinoma. The original lesions were located as follows: two on the nose, three on the nasolabial folds, three on the temporal region and four on the forehead-orbit.

#### SUMMARY

1. A clinical and statistical study of 1062 basal, squamous and basosquamous carcinomata is presented.
2. The "dyontogenic origin" of basal cell carcinoma could not be confirmed, but, rather, uncleanness is stressed as a contributory factor for the development of facial cancer.
3. It was found that on the average there was about a year's elapse with basal cell carcinoma and about three months with squamous cell carcinoma before consultation.
4. All facial cancer spreads by direct extension.
5. Clinically, basal and squamous cell carcinoma can generally be differentiated by the experienced eye.
6. Since basal carcinoma does not metastasize and squamous cell carcinoma of the face only rarely, routine lymph node dissection is not recommended. Frequent metastases to the regional lymph nodes were found in squamous cell carcinoma of the ear. Therefore, radical surgery with frequent lymph node dissection is advocated.
7. All lesions were progressive. No spontaneous healing was observed.
8. Twenty per cent of the cases were recurrent lesions with the history of an inadequate previous treatment and in those cases it was gratifying to find equally good results with control by surgery.

9. The indications for electrodesiccation and radiation therapy are discussed. Surgical treatment is advocated in preference as it gives higher percentage of arrest and often superior cosmetic results.

10. Advanced cases were also treated by radical surgery, preferably using the high frequency currents. It resulted in some arrest or palliation of the disease in the majority of cases.

11. Reconstruction should be made preferably at the time of the operation, although in some cases it is wiser to postpone the closure of the defect for a longer period.

12. The percentage of five- and ten-year arrests of the primary and recurrent lesions are given.

13. Follow-up examinations are advocated as the key to successful treatment and to scientific studies.

14. Although there is still an unduly high percentage of mortality from skin cancer, adequate treatment by qualified surgeons should materially reduce it in the future.

The author wishes to express his thanks to Dr. Carl Eggers for the guidance and constructive criticism in this material, and wishes to pay tribute to the members of the Surgical Staff, including Colonel William F. MacFee, Colonel Robert H. Kennedy and Lt. Col. Herbert W. Meier, now in the armed forces, whose splendid work can be measured only by the results.

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# TRAUMATIC ANEURYSM OF THE FIRST PORTION OF THE LEFT VERTEBRAL ARTERY

## CASE REPORT

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ANEURYSMS of the cervical (extracranial) portion of the vertebral artery are seldom encountered. In the collected literature of the subject only Cattellica (Perrig)<sup>1</sup> and Küttner<sup>2</sup> have described more than one case. Nevertheless, two fine reviews of traumatism of the vertebral artery have been recorded, one by Matas,<sup>3</sup> in 1893, the other by Perrig, in 1932. Matas' lucid and comprehensive exposition tabulated 22 cases of wounds of the cervical portion of the vertebral artery, of which 19 died as a consequence; and 20 cases of aneurysm, of which only six survived, one a case of his own. Perrig, with the reports of World War I from which to draw, was able to collect 40 cases of traumatism and 60 cases of extracranial aneurysm. He appended to his discussion abstracts of all these cases. In the group of aneurysms only 48 impress me as *bona fide* cases of traumatic aneurysm of the cervical portion of the vessel, four cases failing to indicate if trauma was a factor, and eight giving no history of trauma. A more detailed analysis of the abstracts shows that of these 60 cases, traumatic or otherwise, the aneurysm arose in the first (extraspinal) portion in six instances, while in another eight cases this was the probable site. The second (intraspinous) portion of the vessel was clearly, or probably, involved in 28 instances. In the remaining 18 cases the affected site could not be ascertained. At least 28 of the 60 cases died as a direct consequence of the lesion, or its treatment. Of the remaining 32 cases, cures were recorded in 19, improvement in one, and recurrence in one, while in 11 cases the outcome was not indicated.

Aside from these in the reports of Matas and Perrig, other case reports have been made by Giglio,<sup>4</sup> Drügg and Siegmund,<sup>5</sup> Barraud,<sup>6</sup> Spath,<sup>7</sup> Ogilvie,<sup>8</sup> and Meurer.<sup>9</sup> In each of these cases the aneurysm arose from the intraspinal or suboccipital segment of the vessel. Three were traumatic in origin, and cures were effected by surgical means in these instances. Barraud's case was diagnosed at autopsy, while that of Drügg and Siegmund succumbed to postoperative infection. The outcome in Ogilvie's case was not recorded. The American literature includes only the three mentioned by Matas, his own and those of Stone,<sup>10</sup> and Fenger (Matas<sup>3</sup>).

Nearly all cases of aneurysm of the cervical portion of the vertebral artery result from traumatism, either by gunfire or by stabbing. That the vertebral artery is seldom subject to direct trauma is understandable by a consideration of its location. It arises as the first branch of the ascending

portion of the subclavian artery, just medial to the anterior scalenus muscle. Ascending obliquely along the lateral margin of the longus coli, it enters the foramen of the transverse process of the sixth cervical vertebra. This extra-spinous portion of the artery is about one and one-half inches long. Its great depth can be realized from the list of the important structures which overlie it—the thyrocervical trunk, the carotid artery, the internal jugular vein, the omohyoid muscle, the sternocleidomastoid muscle, and the transverse portion of the external jugular vein. The location of these structures lessens the chances of an isolated injury to the vertebral artery. Perhaps these injuries have occurred more frequently than reported, but were unrecognized because damage to the other vessels caused the subject's rapid exitus or drew the observer's exclusive attention. The intraspinous portion of the artery begins at the transverse process of the sixth cervical vertebra, ascends through the foramina of the transverse processes of the proximal vertebrae, runs toward the median line in the groove upon the upper surface of the posterior arch of the atlas, whence it enters the skull after penetrating the atlanto-occipital membrane. We are not concerned here with the intracranial portion, except to mention that it joins with its fellow of the opposite side to form the basilar artery. This anastomosis will be mentioned later in a consideration of the treatment. It might be expected that injury to the second portion of the vessel would be prevented by the vertebral transverse processes, but this is not always the case, for the traumatic agent may have enough room to enter between the transverse processes (the intertransverse spaces are sometimes wider than the transverse processes) moreover, several cases have resulted from comminuted fractures of the transverse processes. The additional fact that this area of the neck, especially the suboccipital region, is more accessible to trauma perhaps explains a greater frequency of aneurysm in the second than in the first portion of the vessel.

The preoperative or premortem diagnosis of aneurysm of the cervical portion of the vertebral artery is most difficult to make. The appearance of a pulsatile swelling following a trauma to the neck is generally deduced to occur in connection with the larger vessels. This mistake has been so frequent that ligations of the common carotid artery were erroneously performed in well over half the cases.\* In only two of Perrig's case abstracts was the diagnosis suspected prior to operation. In one, the presence of a fracture of the transverse process with the bullet *in situ* was the lead, while in the other location of the swelling in the atlanto-occipital region presented the clue to the surgeon. In Meurer's case the diagnosis was accurately made by arteriography; after failure to demonstrate the sac by carotid arteriography, injection directly into the sac established its origin.

In my case the usual error in diagnosis was made, and it was not until the second operation that the true nature of the lesion was realized. Since

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\* Matas has emphasized the importance of avoiding this error by pointing out that ligation of the common carotid artery throws the added strain of the anastomosing circulation on the vertebral artery, which aggravates the lesion.



previous reports have not, or could not, always indicate the exact site of origin of the aneurysm, it can be only conjectured that this case represents anywhere from the seventh to the fifteenth reported case of aneurysm of the extraspinous portion, and from the third to the fifth cure obtained in this type of case.

**Case Report.**—W. M. H., female, age 27, was seen in the receiving room of the Homer G. Phillips Hospital at 7:30 P.M., May 15, 1944, shortly after she was stabbed with a thin-bladed pocket knife during an altercation. Her appearance indicated that she had lost considerable blood. A three-quarter-inch linear vertical laceration was present on the left side of the neck four inches below and anterior to the mastoid process, overlying the middle of the sternomastoid muscle behind its anterior border. Blood pressure 120/80; temperature 98.6° F., pulse 88; respirations 22. A loud to-and-fro machinery murmur was heard over the aortic area. At 8:00 P.M. the skin was sutured, and she was admitted to the hospital ward because the surgeon was not satisfied that the bleeding



FIG. 1.—Appearance of the aneurysmal swelling fourteen days after the stabbing. The healed stab wound is visible.

was controlled. At 10:00 P.M., on account of continued "spouting" of blood, the wound was reopened, and an unsuccessful attempt made to locate the bleeding point; following which the wound was left open and a pressure dressing applied. At 11:00 P.M. the W. B. C. was 7,200; R. B. C. 2,800,000, and hemoglobin 58 per cent. On May 17, there being no further bleeding, secondary closure of the wound was effected, and the patient was discharged from the hospital the following day.

She was readmitted, May 29, 1944, a pulsatile mass having formed at the site of the wound, which had healed *per primam*. The swelling was first noticed about five days after she left the hospital, and steadily increased in size. Concomitantly, she became aware of "pounding" in the neck and "roaring" in the ear, which would sometimes keep her awake at night. In her past history it was noted that, in 1936, she received incomplete antiluetic therapy, and that, in 1939, she had sustained a laceration in the right supra-sternal region of the neck from a kick, the scar of which was still visible. Her recent laceration was well healed. Underlying and inferior to it, approximately three inches below the angle of the jaw, was a bulge about two inches in diameter and elevated

an inch above the surrounding skin surface (Fig. 1). It was visibly as well as palpably pulsatile, and a vigorous thrill was present. Loud systolic and diastolic bruits were heard, the former phase being the more prominent. The mass could be almost completely compressed, but without appreciably diminishing the thrill. A loud machinery murmur could be heard in the aortic and pulmonic areas, and as the neck was approached this merged into the bruit described above. The blood pressure of the left arm was 124/85, that of the right 128/86. It was thought that we were dealing with an arteriovenous aneurysm between the left common carotid artery and the left internal jugular vein, or with a sacular aneurysm of the common carotid artery. Laboratory data: W. B. C. 7,400; R. B. C. 3,500,000, hemoglobin 78 per cent; uranalysis negative; Kahn negative; N. P. N. 18; total proteins 6.33, A/G ratio 1.6.

*First Operation.*—June 3, 1944: Under intravenous pentothal-sodium anesthesia (88 cc. of 2.5 per cent solution were used), an incision four inches long was made over the middle of the left sternomastoid muscle parallel with its anterior border, the upper end reopening the healed stab wound. After division of the deep cervical fascia and posterior retraction of the sternomastoid muscle, a forcibly pulsating, thin-walled aneurysm was exposed. The dissection had as its initial aim exposure of the common carotid artery and the internal jugular vein. They were found to lie anterior and medial to the aneurysm, with which they were seen to have no connection. An attempt to isolate completely the sac met with failure because of its dense adherence to the surrounding muscles and fascia. It was determined, however, that the wall extended inferiorly at least to the level of the clavicle, that its medial and posterior aspects were much deeper than the dissection, and that the aneurysm was larger than was apparent on external examination. It was surmised that the aneurysm originated in the subclavian artery. The operation had already lasted two and one-half hours, and, being somewhat indecisive as to further procedure and hesitant to subject the patient to a protracted exercise, I decided to abandon further surgical measures for the time being. The deep cervical fascia was tightly repaired to compress the aneurysm, and the wound closed.

*Postoperative Course.*—This was uneventful; and the incision healed *per primam*. However, the visible aneurysm increased to twice its preoperative size, and there was a parallel augmentation of the roaring sensation in the head and neck and in the resultant sleeplessness. Accordingly, a second operation was advised, and this time exposure of the subclavian artery was contemplated. The laboratory data at this time was not significantly altered from that previously reported.

*Second Operation.*—June 26, 1944: Under intravenous pentothal-sodium anesthesia (75 cc. of 2.5 per cent solution were used), an incision was made along the anterior margin of the left sternomastoid muscle about three-quarters of an inch anterior to the healed incision, the upper end reaching to the same level, and the lower end extending over the left sternoclavicular joint and along the left border of the sternum for one and one-half inches. A second three-inch long incision along the lower border of the clavicle was made to meet the first incision. The common carotid artery and internal jugular vein were isolated as in the previous operation. During the dissection of the skin flaps the thin adherent wall of the aneurysm was accidentally opened causing an active outpouring of arterial blood. Insertion of the index finger fortunately controlled the blood loss and afforded palpation of the inside of the sac. This was found to extend upward to the level of the transverse process of the fourth cervical vertebra, to lie medially and posteriorly against the vertebral column, and to extend below behind the clavicle. An internal, fairly rigid, ovoid opening one-half inch in its widest diameter, could be palpated against the transverse process of the sixth cervical vertebra, but the finger could not be inserted sufficiently through the opening to ascertain the genesis of the sac. Early isolation of the subclavian artery now seemed imperative. An assistant assiduously kept his finger inserted through the rent for the control of bleeding. The sternomastoid muscle was disjoined at the clavicle and sternum, the omohyoid was divided lateral to its central tendon, and the left sternohyoid muscle was severed at

the upper margin of the sternum. The medial fourth of the clavicle and the upper one and one-half inches of the left half of the sternum were resected. The internal jugular vein was divided near its confluence with the subclavian vein. Lateral retraction of the anterior scalenus muscle then permitted the exposure of the ascending portion of the subclavian artery. When no connection between this vessel and the aneurysm could be found, it was concluded that the vertebral artery was the affected vessel (Fig. 2). Dissection along the inferior margin of the sac exposed the origin of the vertebral artery, arising from the medial aspect of the subclavian as its first branch. Practically at its

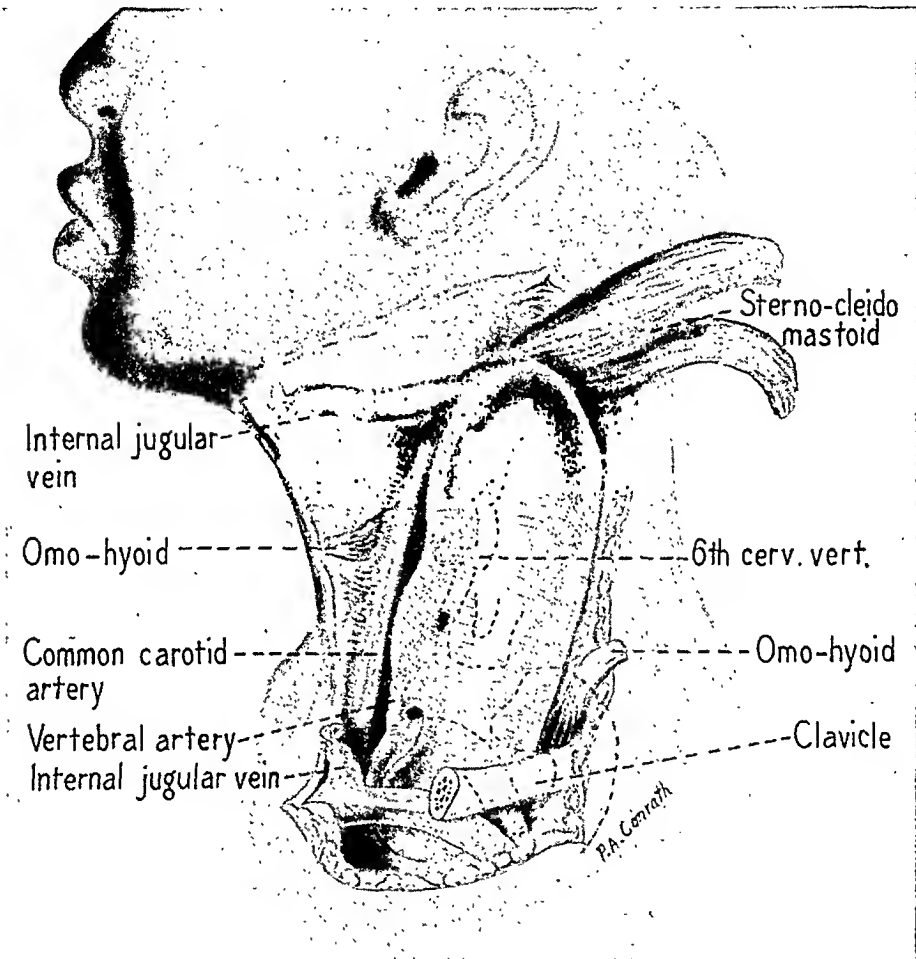


FIG. 2.—Aneurysm of the extraspinal segment of the left vertebral artery. The lower end of the sac is displaced laterally and posteriorly to demonstrate the origin from the vertebral artery. The drawing is largely schematic because of the complexity of structures in the vicinity and because the exact limits of the sac were not determined at operation.

origin the vertebral artery merged with the aneurysm wall. Further proof that we were dealing with an aneurysm of the first portion of the vertebral artery could be deduced by bimanual palpation—the index finger of the right hand in the sac, that of the left outside. When the subclavian artery was compressed, the pulsation and thrill diminished. Believing that occlusion of this vessel would control the blood flow, the vessel was doubly ligated with heavy linen in its first portion, proximal to the origin of the vertebral artery.\* This promptly caused cessation of the radial pulse and blood pressure of the left arm, but the extremity remained warm during the remainder of the operation. Our trust

\* Halsted<sup>11</sup> has shown that ligation of the subclavian artery in its first portion may be performed without depriving the upper extremity of its arterial supply.

that this would control the blood flow was "jolted" upon removal of the digit, which permitted almost as much blood to flow as before the ligation. The small segment of vertebral artery between the subclavian artery and the sac was then ligated and divided, but this also did not appreciably alter the blood flow or the thrill. It was, accordingly, concluded that the aneurysm was being replenished by the distal collateral circulation. A plan to enlarge the opening originally made into the sac for the purpose of attempting an endo-aneurysmorrhaphy had to be abandoned because the field became obscured with blood before adequate exposure could be obtained. Distal ligation of the vertebral artery was out of the question from this approach and at this stage. It was, therefore, decided to tamponade the sac with live muscle transplants. Three blocks of skeletal



FIG. 3.—Appearance of the neck three months after operation. The swelling has disappeared as a result of obliteration of the aneurysm.

muscle excised from the sternomastoid and pectoralis major muscles were packed so as to fill tightly the entire sac. Care was taken to insert the first muscle transplant to occlude the opening at the transverse process of the sixth vertebra. This caused an immediate cessation of the pulsation and thrill. The rent in the sac was then closed over the transplanted muscle with two layers of interrupted cotton sutures. The wound was closed without drainage, no attempt being made to suture the divided muscles. The duration of the operation was four hours and forty minutes; and with the aid of 1500 cc of 5 per cent glucose and 1000 cc. of whole blood intravenously, the pulse and blood pressure were maintained at a constant level.

*Postoperative Course.*—This was quite satisfactory. The pulse rate rose to 132 eight hours after the operation, but dropped to normal by the second day. The temperature rose to 102° F. 24 hours after operation, but this, likewise, promptly returned to normal. The blood counts and chemistry were within normal limits on June 29. The only complication was the collection of about 5 cc. of turbid yellow fluid, which, on July 5, was expressed from a subcutaneous pocket at the middle of the vertical incision. At this time no pulsation or bruit was present, although the firm obliterated aneurysm swelling was readily seen and felt. The blood pressure and radial pulse were still absent from the left upper extremity. There was no complaint of roaring in the ear and sleeplessness.

*Subsequent Course.*—The patient was discharged from the hospital on July 12, the wound having completely healed. The aneurysm swelling had appreciably diminished. Through some of the postoperative course there were complaints of aching pains in the left upper extremity and shoulder, but aside from a slight weakness of this extremity the muscular control was quite satisfactory. The to-and-fro murmur heard in the aortic region from the date of her original admission had, likewise, disappeared—proving that this sound had been transmitted from the neck.

By August 11, the swelling had completely vanished (Fig. 3), and no pulsation or bruit could be detected. No deformity of the neck due to the severance of muscles or resection of bone was present, and motion of the head was unlimited in all directions. The left radial pulse was barely perceptible, but no blood pressure reading could be obtained from the left arm. Re-examination on October 13 showed no appreciable change. The only complaint on this date was an occasional aching pain in the left shoulder.

*DISCUSSION.*—Any discussion of the treatment of aneurysm of the cervical portion of the vertebral artery should be prefaced by the assertion that no one has had sufficient experience with these cases to design a dependable approach. Nor does expertness in the management of aneurysms elsewhere necessarily condition the surgeon for proficiency with the unique anatomic considerations here. We have already mentioned the depth of the vertebral artery and the complexity of structures guarding its access. The singular course of the vessel within the vertebral transverse processes adds to the intricacy of approach as well as to the shaping of the contour of the sac, and this is particularly true when the aneurysm arises from the intraspinal portion. Still another unique feature is the spacious anastomosis with its fellow vessel of the opposite side and its communication with the circle of Willis. It is on account of this feature that proximal ligation proved futile in controlling the flow of blood in my case. Both proximal and distal ligation, as advocated by Matas, would seem to be a highly desirable procedure, but has been successfully accomplished in only three cases. That the proximal ligation can be performed has been demonstrated not only in a number of the cases under discussion, but also in cases of epilepsy, where the operation was performed with some frequency toward the end of the last century. The achievement of distal ligation should be feasible if we relinquish the thought of attempting it low in the neck, and approach the vessel, if necessary through a separate incision, posteriorly below the occiput. However, it must be admitted that fulfillment of this objective is usually both hazardous and arduous. Moreover, it is not certain that double ligation would assure a complete and permanent obliteration of the aneurysm, since the existence of other collateral circulation has been noted (Küttner).

All things considered, it would seem that cure could be better assured if the aneurysm sac was directly approached. As with aneurysms elsewhere, extirpation of the sac with double ligation would be the choice, but the probability of achieving this in any but the most favorable circumstances is remote. A variety of other less radical procedures have been tried, including injection of irritants and sclerosing media, electropuncture and electrolysis. Endo-aneurysmorrhaphy has been employed only in Spath's case. The method

which has appealed to the judgment of most operators is treatment by incision and tamponade. That this method was oftentimes employed may be a reflection on the frequency with which the surgeon found himself in a desperate predicament. There is scarcely anything surgically so instinctive as tamponading an exsanguinating operative site. Of the 16 cases in which the aneurysm was opened (usually accidentally) and packed, cures were obtained in ten—a relatively high percentage. In most cases the packing consisted of gauze impregnated with antiseptics and astringents; in several cases ligation of the proximal vessel was an adjunct.

Küttner introduced the utilization of muscle transplants as the tampon in two of the three cases which came under his observation. In each instance proximal ligation failed to control the blood flow. In one, distal ligation was attempted but could not be effected. Free muscle transplants consisting of about 15 to 20 small fragments derived from the adjacent muscles were, accordingly, packed through the incised opening into the sac, the wall of which was sutured tightly over the transplants. The successful outcome in both these cases prompted him to suggest this method as the treatment of choice, and the gratifying result of my case would seem to substantiate his recommendation. It is apparently not necessary to use large numbers of small transplants. The size of the grafts need only be limited by the size of the opening through which they are to be inserted. The question naturally arises as to whether proximal ligation is a necessary adjunct to the success of this procedure. Of course, no unequivocal answer can be forthcoming. Nevertheless, it is apparent that this, not too risky, ligation might decrease the blood current sufficiently to permit adherence and organization of the transplant.

The use of pedicled and free muscle transplants in aneurysms of the subclavian and femoral arteries has been described by McNealy and Shapiro.<sup>12</sup> They demonstrated experimentally, that muscle transplants adhere to the intima by the development of a proliferative endarteritis, and that recanalization does not occur. Previously, I had the opportunity to employ a pedicled muscle transplant to obliterate an aneurysm of the posterior tibial artery. The present case is additional evidence that this is a feasible, as well as a desirable, method of managing those arterial aneurysms not requiring restoration of the blood flow, and whose extirpation or obliteration by other means would proffer inordinate hazards. Since the vertebral artery is of medium caliber, the use of muscle transplants in aneurysms of this vessel would seem to offer a better hope for cure than in those of larger vessels.

#### SUMMARY

A case of aneurysm of the first portion of the left vertebral artery resulting from a stab wound is described. A complete cure resulted from the use of autogenous muscle transplants directly into the sac, after proximal ligation failed to control the flow of blood.

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# STRICTURE OF THE FEMALE URETHRA WITH LYMPHOPATHIA VENEREA

LYMPHOGRANULOMA INGUINALE

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IN RECENT YEARS gynecologists and urologists are becoming more and more interested in strictures of the female urethra. Many authors state, that such strictures are rare, others say, that the frequency and importance of this ailment are not enough emphasized. We believe that strictures of less degree are not infrequent, but the more severe type, as illustrated by the case to be reported, is very rare.

**Case Report.**—Mrs. M. B., colored, age 41, was admitted to the Gynecological Service of Dr. William R. Nicholson, June 11, 1944, complaining of great difficulty in voiding her urine. She states that ten years ago on a very cold day she had to wait for a trolley car a very long time, and arriving at the factory she felt cold "up to the navel." She was unable to pass urine, and on her way home she started dribbling and felt wet. Her family physician could not pass a catheter and ordered a medicine which improved the condition temporarily. Since this time the patient has been forced to be under medical care.

The patient gave birth to one child 24 years ago, and had three miscarriages in the last five years. Menstruation started at age 14, was regular every 28 days, lasting 3-5 days, with moderate flow and slight cramps on the first day. As a child she had measles and mumps but no history of scarlet fever or diphtheria. In 1940, a urethral stricture was treated by dilatation. In 1943, a bilateral salpingectomy and appendicectomy was performed.

**Physical Examination.**—Female colored patient, in general good condition. Blood: R. B. C. 3,860,000, 63 per cent hemoglobin; W. B. C. 9,400, 68 per cent neutrophils, 2 monocytes, 30 per cent lymphocytes.

The vagina and uterus were normal. No abnormal resistance could be detected in the pelvis. The urethra was extremely narrowed and only allowed the passage of a filiform ureteral catheter, by which the greatly overdistended bladder was evacuated. Wassermann reaction was negative.

The diagnosis of a tight stricture of the upper half of the urethra was self-evident, but the etiologic explanation was at first difficult.

A study of the world literature shows that a great number of diseases can cause stricture of the female urethra. Wynne<sup>57</sup> classified strictures as traumatic, inflammatory, neoplastic, congenital, senile and unknown.

In the herein reported case, injury during childbirth can be excluded as the *partus* was 24 years ago and the first onset of urinary retention ten years ago, therefore, 14 years after the delivery. There is also no history of accidental injury, burns, scalds, previous operations or the application of strong caustics, pointing to a traumatic cause.

Inflammatory diseases causing urethral strictures in the female as syphilis, tuberculosis and chancroid are excluded as causal factors, because of the



absence of positive specific reactions in this patient. The history also does not show diseases which sometimes cause ulceration of the vulva, such as scarlet fever and diphtheria.<sup>39, 43</sup> Gonorrhea, the most common cause of urethral stricture in the male, but a very rare cause in the female, can not be considered as etiologic factor since gonococci were never found. No benign or malignant new growths, responsible for the urethral stricture,<sup>26, 35</sup> were in evidence. A congenital etiology<sup>19, 31, 51</sup> is out of the question as patient had the first symptoms at the age of 31.

The only positive finding in the herein reported case was a *positive Frei test*, which proves that the patient suffers from lymphopathia venerea. Whether or not this disease is a possible etiologic factor in stricture formation of the female urethra will now be considered.

Before we discuss this question, it seems to be necessary for the sake of clearness, to discuss the different types of lymphopathia venerea, together with the possibility of the involvement of the urethra and the pathology of stricture formation.

#### LYMPHOPATHIA VENEREA AND THE INVOLVEMENT OF THE URETHRA IN THIS DISEASE

The different names given by various authors to lymphopathia venerea have not contributed to clear up the knowledge of this disease. Thus some authors suggested "subacute inguinal lymphogranulomatosis",<sup>46</sup> others named it "climatic bubo."<sup>18, 19, 42</sup> It has also been given such names as "the fourth venereal disease," "tropical bubo,"<sup>55</sup> "subacute inguinal poradenitis," "strumous bubo," "subacute inguinal lymphadenitis," "inguinal poradenitis"<sup>6</sup> "inguinal adenopathy," "pestis minor," "granuloma venereum"<sup>5</sup> and "nontuberculous granulomatous lymphadenitis." The term lymphogranuloma inguinale seems to be used most extensively in European literature, though it must be emphasized *that this term really designates an entirely different condition from granuloma inguinale*. To distinguish between these diseases we prefer, and will use, *lymphopathia venerea* instead of lymphogranuloma inguinale. *Lymphopathia venerea is a disease of the lymph channels and of the nodes, due to a filtrable virus and gives a positive Frei test. Granuloma inguinale involves the skin and subcutaneous tissue, and is due to the Donovan bodies.*

The different forms, in which lymphopathia venerea occurs, and its different manifestations in the two sexes, are of the utmost importance.

Nelson<sup>45</sup> states that lymphopathia venerea in the *male* is usually characterized by inguinal adenitis, although elephantiasis of the genitalia does occur and rectal stricture is not rare. In the *female*, the characteristic lesions are: Chronic ulceration of the vulva, perineum, anus and rectum; fistula formation; and rectal stricture, their combination forming the genito-anorectal syndrome. Inguinal adenitis does occur, however, in some females.

The lymphopathic infection of the *urethral* mucosa may occur in different forms: as erosion, as superficial ulcer, and as seropurulent inflammation.

Kleeberg (1931)<sup>32, 33, 34</sup> describes a *stricture of a male urethra* in a case with a *positive Frei test*, and states his case was the *first one of urethral stric-*

ture in *lymphopathia venerea*, and compares this condition with the stricture of the rectum.

Touraine (1936)<sup>52, 53, 54</sup> differentiates a "*syndrome postérieur*" and a "*syndrome antérieur*," according to the localisation of the lymphopathic lesion, besides the involvement of the entire genital area. The posterior syndrome is usually combined with an anorectal stricture. The anterior syndrome shows, in a similar way, a stenosis of the *urethra*. He describes a case of elephantiasis of the vulva without perineal lesions and without anorectal involvement, but with urethritis and subsequent *stricture of the urethra*. The Frei test was positive.

#### PATHOLOGY OF STRICTURE FORMATION

It should again be emphasized that there is a variation in the form of the disease in men and women, *as result of differences in the distribution of the lymphatic drainage*.

A careful review of studies on the lymph supply of the male and female genitalia has shown that the lymph-nodal reactions of the disease are dependent on the lymph drainage.<sup>1, 27</sup> In the *male*, most of the lymph channels of the genitalia drain into the inguinal and, secondarily, into the deeper iliac nodes. Therefore, these nodes are the ones most often affected. *In the female, on the contrary, only the lymph from the clitoris and external vulva drains into the inguinal nodes while the supply from the vaginal mucosa, and especially from the posterior vaginal wall, drains into the lymph nodes around the rectum, where there are three lymph plexuses extending together up in the rectum to a height of from four to six centimeters.* Consequently, rectal stricture is much more common in females than in males, who suffer from this disease. Only the lower six centimeters of the rectum is involved as a rule, although it may extend upwards as high as ten centimeters. The tendency of the infection of the rectal and pelvic lymph nodes in the female is to produce an inflammation which spreads to the rectal walls through the lymph channels. Later, lymph obstructions take place. The end-result is inflammation and scar formation, with narrowing of the rectal lumen. The stricture may be band-like or, if all the lymph plexuses are involved, tubular in character.

The problem which presents itself is whether the well known stricture formation in the rectum in female cases of *lymphopathia venerea* allows us to assume that a urethral stricture in a female is analogous to the rectal condition. The above analysed lymph supply gives the explanation for the rectal stricture in females, where the lymph supply from the vaginal mucosa and posterior vaginal wall drains into the lymph nodes around the rectum. The lymphatics of the whole urethra in the female pass to the hypogastric nodes.<sup>21</sup> This is the reason why we do not find enlarged inguinal nodes in case of involvement of the urethra alone. A stricture of the urethra caused by lymphopathic disease can only be explained by a primary involvement of the urethral mucosa and the lymphatics in the immediate neighborhood.

In the rectal stricture the inflammation spreads to the rectal walls through the lymph channels *from the outside of the rectum*. In the urethra a primary involvement of the mucosa takes place, and the infection spreads through the lymph channels *from the urethral mucous membrane*, forming scars with stricture formation of the urethra as a result.

#### THE VALUE OF THE FREI TEST

The diagnosis of lymphopathia venerea has been greatly simplified by the discovery Frei announced late in 1925.

In patients suffering from lymphopathia venerea, or in those who have previously had the disease, an intradermal injection of 0.1 cc. of his antigen produces an inflammatory papule within 24 hours, which persists for several days or longer. This specific cutaneous sensitivity lasts for many years, *perhaps during the life of the patient*, in other words, the patient develops an allergic state. One reported case showed a positive reaction after 23 years,<sup>21</sup> and another a positive reaction after 30 years.<sup>2</sup>

The fact that a patient is suffering from lymphopathia venerea does not prove that the lymphopathia venerea stands in causal relation to her urethral stricture. A case of proved lymphopathia venerea may develop an urethral stricture due to a trauma during a delivery, and in such a case we would find the combination of stricture of the urethra and a positive Frei test. In the case herein presented, there was no history of trauma and after a careful study of possible etiologic factors, all such causes for stricture of the female urethra can be excluded.

Study of the literature has shown that cases of primary and isolated lymphopathic infection of the urethra occur.<sup>34, 44, 52, 53</sup> We know that lymphopathia venerea affects the lymphatics, causing marked stricture formation. Therefore, the positive Frei test makes it more than probable that there is a causative connection between the urethral stricture and the lymphopathia venerea in this case. It is, therefore, advisable in any case of urethral stricture of unknown etiology to make a Frei test and, if positive, to reconsider the case from this angle. The test should also be made if the Wassermann reaction is positive, since fresh cases of lymphopathia venerea, for a period of time during the acute stage of the disease, occasionally will give false positive Wassermann reactions.<sup>2</sup> This is a very important finding, as a 3-plus Wassermann reaction in a patient with lymphopathia venerea might easily be mistaken for syphilis and treatment instituted.

#### TREATMENT

Kelly<sup>30</sup> says a stricture of the urethra may be treated by one of the following methods: Electrolysis, rapid dilatation, slow dilatation, incision and dilatation, and excision.

If the stricture is not too tight nor spread over too large an area, it may be treated by rapid dilatation, putting the patient under gas anesthesia and passing Hegar dilators until the canal is enlarged by two to three millimeters in diameter, or up to the size of the average glass catheter, six to seven

millimeters. After this preliminary rapid dilatation, gradual dilatation, with sounds, bougies or Hegar dilators should be used over a considerable period of time. This operation is carried out after a local anesthetic has been applied to the urethral mucous membrane. The dilating instruments should be generously lubricated before insertion and the largest instrument passed at any sitting should be left in place for 10–15 minutes. The size of the dilators used must be determined each time by the degree of pain caused. It is necessary to avoid any severe pain as the treatment must be so frequently repeated, and, also, to avoid trauma. At first daily treatments are given, but later the intervals between sittings can be increased and the treatments should be continued over a period of several months.

These patients ought to be warned that recurrences are common, and that for this reason they are to return several times a year for dilatation. In some cases reported the dilators were left in place for six hours. If the patient is sufficiently intelligent it is a good plan to give her a dilator of the largest size and instruct her how to sterilize it, to cleanse the parts and to introduce it well oiled. This she ought to do every day and report for further examination several weeks later.

In the presented case we treated the patient by rapid dilatation. Under gas anesthesia, the urethra, which only admitted a filiform ureteral catheter, was dilated gradually up to a No. 37 metal dilator. A retention catheter was left in place and a dilatation under local anesthesia was repeated, first daily and later at longer intervals. Now, after three months, the patient is coming for treatment every other week. She feels perfectly well and passes water without any difficulty.

#### SUMMARY

(1) A high-degree stricture of the female urethra in a case with positive Frei test has been presented.

(2) The involvement of the female urethra in lymphopathia venerea has been discussed.

(3) The differences in the pathology of rectal and urethral strictures have been pointed out.

(4) The value of the Frei test as an etiologic guide, and the probability of the lymphopathic origin of the presented case has been discussed.

(5) The Frei test in each case of urethral stricture of doubtful etiology has been suggested.

(6) The treatment of strictures of the female urethra has been described.

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# SERUM AMYLASE FINDINGS IN CHRONIC ALCOHOLIC PATIENTS WITH ACUTE, SEVERE ABDOMINAL SYMPTOMS

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THE PURPOSE of this paper is to emphasize the significance of the high serum amylase values found in a small group of patients admitted to the Surgical Wards of Harlem Hospital "for observation" suffering some apparent severe intra-abdominal condition.

All the patients gave a history of chronic alcoholism and the symptoms upon admission were: vomiting, severe pain in the epigastrium, and, on physical examination, they showed marked rigidity of the abdominal muscles, especially in the upper half of the abdomen, with or without tenderness in the epigastrium. In this type of case members of the Staff have usually made the diagnosis of "acute alcoholic gastritis," while not infrequently the patient has been subjected to an unnecessary exploratory celiotomy for a possible surgical lesion.

Clinically, at times, the lesion seemed to be located in the stomach, while in other cases the pancreas was apparently involved. The last alcoholic debauch evidently precipitated changes in a digestive system that had been impaired by the prolonged excessive use of alcohol. Certainly, the symptoms in some of the patients were much more severe than could be explained on the basis of simple acute gastritis superimposed upon chronic gastric pathology. As a matter of fact, the symptoms were so catastrophic in character that they could be explained on an anaphylactic basis.

TABLE I  
SERUM AMYLASE FINDINGS IN 11 ALCOHOL PATIENTS WITH ACUTE ABDOMINAL SYMPTOMS

Case No.	Operation	Serum Amylase Readings	Urine Amylase Readings	Peritoneal Fluid Amylase Readings
Case 1	Findings: Thin sanguineous fluid in abdominal cavity. Edema about pancreas			
Case 1 (Readmission)	None	340 S.U.		
Case 2	None	607 S.U.		
Case 2 (Readmission)	Findings: Thin sanguineous fluid in abdominal cavity. Edema about pancreas	844 S.U.		415 S.U.
Case 3	Findings: Thin sanguineous fluid in abdominal cavity. Edema about pancreas	350 S.U.	353 S.U.	990 S.U.
Case 4	Findings: Thin sanguineous fluid in abdominal cavity. Edema about pancreas	268 S.U.		
Case 5	None	488 S.U.		
Case 5 (Readmission)	None	348 S.U.		
Case 6	None	942 S.U.	700 S.U.	
Case 7	None	385 S.U.	1524 S.U.	
Case 8	None	455 S.U.		
Case 9	None	332 S.U.		
Case 10	None	280 S.U.		
Case 11	None	370 S.U.		

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The material upon which these studies were based was obtained on 11 patients, as shown in Table I. Four operations were performed, and in each instance edema about the pancreas was noted, and the peritoneal fluid was of a thin sanguineous character. In the remaining seven cases the high amylase findings were the chief factor in deciding against operative intervention. These seven cases were discharged well. In Cases 2 and 3, amylase readings were made of the peritoneal fluid in addition to the readings in the serum, while in Cases 3, 6 and 7 determinations were also made on the urine. The peritoneal fluid readings and urine amylase readings were above normal.

Wright<sup>1</sup> found, roentgenologically, when cats were fed with a barium carbohydrate, barium protein, or barium fat mixture, to which large doses of alcohol had been added, that the rate of discharge from the stomach was greatly delayed. The chemicophysilogic basis for this mechanism is not entirely clear, but it involves local effects on the organs of the digestive system as well as action on the central nervous system.

It is well known in man that the consumption of large quantities of alcohol causes a transient stimulating action rapidly followed by grave depression. Berry<sup>2</sup> made gastroscopic studies on a large number of chronic alcoholic patients and noted definite changes in the gastric mucosa, which proved the existence of a chronic alcoholic gastritis.

Clark<sup>3</sup> studied 36 cases at autopsy, and found that there was a definite relationship between habitual drunkenness and pancreatitis. He noted inspissated or coagulated secretions in the pancreatic duct of 36 cases; combined with this was dilatation of smaller ducts in areas of fibrosis. A review of the histories of many patients with pancreatic cysts has shown that they were heavy consumers of alcohol.

The cause of elevated amylase in the serum of human beings is considered to be due to rapid destruction of the acinar membranes of the pancreas and the sudden overflow in the immediate surrounding pancreatic tissue which cannot hold or confine it; the enzyme thus escapes into the blood stream. Its presence in the urine and peritoneal fluid can be explained on the same basis.

COMMENT.—In Table I it is seen that operation was performed in four instances and in these four patients edema was present about the pancreas. Operation was avoided in seven instances in the presence of severe abdominal signs and symptoms, and the patients recovered without surgery. Three cases represented readmissions, and in all three instances there were persistently high urine amylase readings.

#### CASE REPORTS

**Case 1.**—J. E., male, chronic alcoholic, admitted January 20, 1939, was operated upon for a possible ruptured ulcer. At operation, the diagnosis of acute pancreatitis was made. One month later he was readmitted with a similar history and complaint, but this time an elevated amylase prevented a repetition of the first error.

**History.**—Patient is a chronic alcoholic who entered with an attack of severe abdominal pain following a drinking bout. He was taken to another hospital where a

diagnosis of ruptured peptic ulcer was made, but patient refused celiotomy. He was then brought to Harlem Hospital where the diagnoses were made of: 1, ruptured appendix with generalized peritonitis; 2, ruptured peptic ulcer.

*Operation.*—Findings: Large amount of thin hemorrhagic fluid found in the peritoneal cavity. The pancreas was found to be edematous and enlarged. The diagnosis of acute hemorrhagic pancreatitis was made.

*Course.*—Patient developed delirium tremens and was transferred to Bellevue Psychiatric Ward. *Final Diagnosis:* Acute hemorrhagic pancreatitis.

*Second Admission, February 19, 1939.*

*History.*—Chronic alcoholic admitted with severe abdominal pains of nine days' duration. There had been persistent vomiting. Abdomen was distended and rigid. There was marked direct and rebound tenderness present. *Diagnosis:* Acute pancreatitis.

*Laboratory.*—Kahn, negative. Urine, occult blood, albumin 2 plus. *Amylase*—Serum, February 19, 1939, 340 S. U.

*Course.*—Continued improvement until discharged February 26, 1939. *Final Diagnosis:* Acute pancreatitis.

*Case 2.*—D. W., male, age 38, was admitted January 15, 1942. He was a chronic alcoholic who entered with symptoms of an acute abdomen. Many diagnoses were made, but a serum amylase of 607 Somogyi units indicated the correct diagnosis and prevented operation. This patient was readmitted one month later, with a similar history and symptoms, but this time he unfortunately came to operation. At operation, the diagnosis of acute pancreatitis was made. The amylase readings were elevated on both plasma and abdominal fluid taken at operation. Patient went into shock and expired.

*History.*—Patient is a chronic alcoholic, and was admitted after suffering sudden abdominal pain. He entered with spasticity and moderate rigidity and tenderness in abdomen. The diagnoses made were: 1, acute abdomen.; 2, left diaphragmatic pleurisy; 3, ruptured appendix, with peritonitis; 4, cholecystitis or pancreatitis; 5, left subphrenic abscess; 6, lobar pneumonia.

*Laboratory:* Kahn, 4 plus. Urine, normal. Chemistry, normal. Roentgenograms showed elevated left diaphragm and questionable pneumonia. *Amylase*—January 15, 1942, 607 S. U.; January 23, 1942, 485 S. U.; February 2, 1942, 10 S. U.

*Final Diagnosis:* 1, Pancreatitis; 2, lues.

*Second Admission, February 20, 1942.*

*History.*—Following a period of heavy drinking he was seized with epigastric pain just to the left of the midline, which radiated along left costal margin. Abdomen was board-like, with marked rebound tenderness. *Diagnosis:* Ruptured ulcer.

*Operation.*—Findings: One liter of serosanguineous fluid in peritoneal cavity. No other pathology found. *Operative Diagnosis:* Acute pancreatitis.

*Laboratory.*—Kahn, 4 plus. Urine, negative. Chemistry, negative. Roentgenologic, essentially negative. *Amylase*—February 20, 1942, plasma 844 S. U., peritoneal fluid 415 S. U. February 24, 1942, plasma 297 units.

*Course.*—Patient went into shock on February 25, 1942, and expired. *Final Diagnosis:* Acute pancreatitis.

*Case 3.*—W. W., male, age 30, was admitted March 9, 1942. The patient was a bartender and was admitted with a diagnosis of acute appendicitis or possible perforated peptic ulcer. At operation, the diagnosis of acute pancreatitis was made. It is significant that amylase readings on abdominal fluid at operation was 990 S. U. whereas the plasma value the following day was only 185 units.

*History.*—Patient was seized with severe abdominal pain, following heavy drinking. Abdomen was flat, with slightly increased resistance in lower half, more rigid in upper one half. *Diagnosis:* 1. Acute appendicitis. 2. Possible perforated peptic ulcer.

*Operative Findings.*—Approximately 300 cc. of hemorrhagic fluid in the peritoneal cavity. Abdomen was closed after inspection of viscera revealed no other pathology.



*Laboratory.*—Kahn—negative. Urine—negative. Chemistry—normal. Roentgenograms of abdomen—essentially negative. *Amylase*—Abdominal fluid 990 units, March 10, 1942. Blood plasma 185 units, March 11, 1942. Blood plasma 350 units, March 16, 1942. Urine 353 units, March 17, 1942.

*Course.*—Discharged March 31, 1942. *Final Diagnosis:* Acute pancreatitis.

*Case 4.*—H. C., male, age 38, was admitted February 24, 1942. The patient was a chronic alcoholic, and entered with a diagnosis of intestinal obstruction. At operation the diagnosis of acute pancreatitis was made. *Serum amylase*, two days postoperative, was 268 S. U. Patient died on fourth postoperative day.

*History.*—The patient is a chronic alcoholic and entered with severe abdominal pain. Vomited several times. Abdominal scar from previous stab wound. Obstipation of two days duration. *Diagnosis:* Acute intestinal obstruction.

*Operative Findings.*—Serosanguineous fluid in abdominal cavity. Hepatic end of transverse colon edematous and hemorrhagic. Fat necrosis on under surface of transverse mesocolon.

*Laboratory.*—Kahn—negative. Urine—negative. Chemistry—normal. *Serum amylase* 268. Roentgenograms of abdomen—negative. W. B. C. 12,200, 84% polynuclears.

*Course.*—Postoperatively, the patient developed delirium tremens, and died on the fourth postoperative day. *Final Diagnosis:* Hemorrhagic pancreatitis.

*Case 5.*—M. H., female, age 22, was admitted March 25, 1941, with the history of chronic alcoholism and complained of pain in abdomen radiating to the back. Rigidity in right upper quadrant. Liver enlarged. *Diagnoses:* 1. Acute catarrhal jaundice. 2. Toxic hepatitis. 3. Gastroenteritis. 4. Acute pancreatitis. 5. Intestinal obstruction. 6. Rupture of sigmoid colon.

*Laboratory.*—Kahn—negative. Urine—negative. Icteric index 6.6. van den Bergh—negative. *Amylase*—March 20, 1941, plasma, 488 S. U. March 26, 1941, plasma, 281 S. U. March 27, 1941, plasma, 114 S. U. April 3, 1941, plasma, 106 S. U.

Patient discharged April 8, 1944, without complaints.

Second Admission, September 21, 1943.

*History.*—Severe abdominal pain and vomiting, following long period of drinking. Patient entered with mild shock, abdomen distended. Liver edge palpated, abdomen tense and tender. *Diagnosis:* Acute alcoholic pancreatitis.

*Laboratory.*—Roentgenogram for air under diaphragm—negative. *Amylase*—Serum 348 S. U., September 21, 1943.

Patient signed out A. O. R. September 22, 1943. *Diagnosis:* Acute alcoholic pancreatitis.

*Case 6.*—C. M., female, age 25, was admitted September 5, 1941.

*History.*—Patient was seized with abdominal pain, cramps and vomiting following heavy drinking, and entered in mild shock, pulse thready and almost imperceptible. Abdomen tense, distended, and rigid. Mouth and tongue showed evidence of avitaminosis. *Diagnoses:* 1. Intestinal obstruction. 2. Retroperitoneal infection. 3. Acute pancreatitis. 4. Acute cholecystitis. 5. Early acute appendicitis.

*Laboratory.*—Kahn—4 plus. Urine—essentially negative. *Amylase*—Serum, September 5, 1941, 942 S. U.; plasma, September 6, 1941, 360 S. U.; urine, September 6, 1941, 700 units per hour excretion of 70 cc.; plasma, September 10, 1941, 70 S. U.

*Final Diagnosis.*—On discharge September 22, 1941, acute pancreatitis. Lues.

Second Admission March 14, 1942.

Readmission, with similar symptoms of pain in the epigastrium. This time she was placed in a medical ward where she remained for four days. Urine and chemistry normal. She was discharged with final diagnosis of alcoholic gastritis.

*Case 7.*—J. T., male, age 38, was admitted September 24, 1942. The patient entered with a rigid abdomen, and a history of drinking cheap liquor. *Diagnoses:* 1. Acute alcoholic gastritis. 2. Chronic alcoholic gastritis.

## SERUM AMYLASE IN THE ALCOHOLIC

*Laboratory.*—*Amylase*: Plasma, September 24, 1942, 385.5 S. U. September 25, 1942, 364 S. U. Urine, September 25, 1942, 1524 S. U.; September 26, 1942, 1524 S. U. Plasma, September 29, 1942, 524 S. U.

*Final Diagnoses*: Acute alcoholic gastritis. Acute pancreatitis.

Case 8.—J. P., male, age 34, was admitted June 6, 1942, complaining of abdominal pain following period of excessive drinking. Abdomen rigid with direct and rebound tenderness. Diagnosis: Acute gastritis.

*Laboratory.*—Kahn—negative. Urine—negative. Roentgenograms of abdomen—negative. *Amylase*—Plasma 455 units.

*Final Diagnosis*.—Acute pancreatitis.

Case 9.—E. G., female, age 32, was admitted May 6, 1943. The patient was a chronic alcoholic, and entered complaining of frequent attacks of vomiting, and pain in the abdomen. She entered hospital two weeks after onset. Diagnoses: 1. Chronic recurrent pancreatitis. 2. Possible peptic ulcer.

*Gastroscopy.*—Impression—chronic gastritis.

*Laboratory.*—Kahn—negative. Urine—negative. Chemistry—negative. *Amylase*—332 units, May 6, 1943.

*Final Diagnoses.*—Chronic gastritis. Chronic pancreatitis.

Case 10.—D. P., male, age 23, was admitted May 6, 1942, with the history of alcoholic excesses for two weeks. Abdominal pain. Rigidity in both upper quadrants. Diagnoses: 1. Acute cholecystitis. 2. Acute appendicitis. 3. Acute abdomen. 4. Pancreatitis. 5. Gastritis. 6. Hepatitis.

*Laboratory.*—Kahn—negative. Urine—negative. Chemistry—negative. Roentgenograms of abdomen—negative. *Amylase*—Plasma, May 6, 1942, 280 units.

*Course.*—Improvement until discharge on May 17, 1942. *Final Diagnosis*: Gastritis.

Case 11.—L. C., male, age 31, was admitted April 6, 1944, complaining of severe abdominal pain following over-indulgence of alcohol. Vomiting present. Diagnoses: 1. Ruptured gastric ulcer. 2. Acute pancreatitis.

Abdominal tap: Thin hemorrhagic fluid.

*Laboratory.*—Roentgenograms of abdomen revealed no air under the diaphragm. *Amylase*—Abdominal fluid, 370 units.

Patient left hospital symptom-free the next day.

### CONCLUSION

Serum amylase determinations should be made on all chronic alcoholic patients if operative intervention is contemplated because of severe, acute abdominal symptoms.

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# MYOBLASTOMA

## CASE REPORT

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TUMORS of the myoblastoma group are being recognized with increasing frequency during recent years and criteria for their classification are pending. The chronologic history of these lesions is relatively brief, the first cases being described in 1926 by Abrikossoff.<sup>1</sup> Klemperer,<sup>2</sup> in 1933, reviewed the subject, discussing 44 cases and adding six new ones of his own. Horn and Stout,<sup>3</sup> of Columbia, in 1943, reported two more cases and reviewed 120. In September of 1944, Warren and Howe<sup>4</sup> reported ten new cases, and reviewed and classified all cases reported to that date, bringing the total to 155.

The typical tumor cell in myoblastoma is a large, pale, faintly acidophilic cell, polyhedral in shape and granular in cytoplasm, which is sometimes vacuolated. Nuclei are relatively uniform in size, shape and staining reaction, and mitotic figures are rare. The cells are frequently seen arranged in a pseudo-alveolar or organoid fashion and sometimes in bands or bundles surrounded by a delicate fibrous tissue stroma. They may resemble xanthoma cells, but staining with scharlach R fails to reveal lipid material. Cross-striations may be present. In event that these cross-striations are present in appreciable number, Howe and Warren<sup>4</sup> believe them better classified as rhabdomyomata or rhabdomyosarcomata. Often a definite capsule is present, but if absent, the tumor cells blend almost imperceptibly with the adjacent muscle cells.

Abrikossoff originally classified myoblastic tumors into four types: Type I being tumors composed of myoblasts with no striations. Type II included cells similar to Type I but with rare longitudinal or cross-striations. Type III was composed of tumors with markedly hypertrophic myoblasts (40-160 micra in length), often multinuclear and syncytial in form. Type IV lesions were tumors which were all typical myoblastic sarcomata, the cells of which showed pleomorphism, with some areas showing differentiation with striations, and others being frankly sarcomatous. Howe and Warren classify Type IV tumors as frank rhabdomyosarcomata.

Generally speaking, malignant and invasive myoblastic tumors are rare, and metastases *via* either lymph or blood stream are unusual. In only 11 per cent of total cases reported was malignancy found, and of these only three showed metastases, the common sites being regional lymph nodes and lungs. Fifty-six per cent of cases, exclusive of Klemperer's series, occurred in the upper respiratory and digestive tracts (114 cases). From the total of 155 cases in the literature 59 were tumors of the tongue, 13 of the oral cavity, 10 of the subcutis, and 73 of the rest of the body.

## MYOBLASTOMA

Some myoblastic tumors are associated with epidermoid malignancy. These usually occur in the upper respiratory tract, mouth (tongue particularly) and skin. In 45 per cent of the 29 cases in which information is available there was excessive epithelial hyperplasia overlying the tumor, and in 28 per cent frank carcinoma.

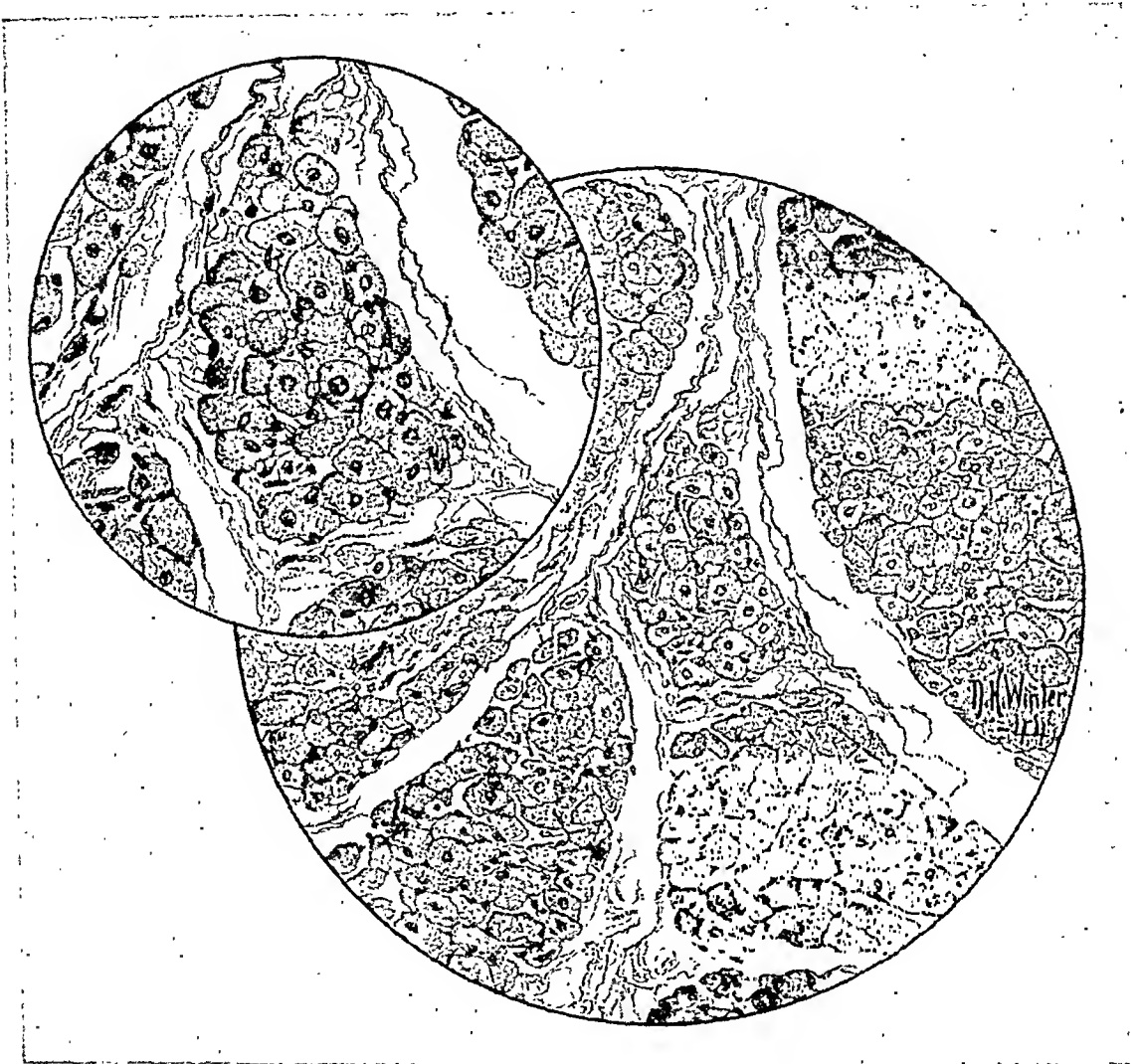


FIG. 1.—Drawing showing cellular structure and pseudo-alveolar arrangement of myoblastoma cells. Inset shows higher power magnification.

**Case Report.**—Mrs. R. E. J., age 48, was admitted to the University of Kansas Hospitals complaining of a mass in the left back, which she first noticed about seven months before. During the past three months the mass has grown rapidly. Some discomfort was noticed when the patient lay on the left side, but there has been no pain.

**Physical Examination.**—A smooth mass was found in the posterior axillary line over the ninth rib, measuring about 5 x 7 cm. It was freely movable on the chest wall and beneath the skin. The consistency was somewhat firmer than that of an ordinary lipoma. A clinical diagnosis was made of a deep-lying lipoma.

**Operation.**—Under local anesthesia, the mass was removed. It lay in the anterior margin of the left latissimus dorsi muscle, and was definitely encapsulated.

**Gross Pathology.**—The specimen consists of a roughly-flattened, encapsulated, spheroidal piece of tissue, measuring 6 x 6 x 2 cm. It is soft, spongy and elastic in con-

sistency. The cut-surface of the specimen appears quite meaty, being made up of pale brown fasciculi of tissue closely resembling striated muscle with little stroma.

*Histopathology.*—The sections are found to be composed of masses of peculiar polyhedral cells separated by a fine, loose fibrillar stroma and arranged in irregularly shaped lobules. These cells are large, pale and moderately eosinophilic, with coarsely granular, often vacuolated cytoplasm. Nuclei are central in location, uniform in morphology, and without mitoses. Masson's stain colors these cells orange-brown, indicating their parenchymatous nature. Striations could not be demonstrated (Fig. 1).

There has been considerable controversy over the origin and pathogenesis of these tumors. Two basic theories are promulgated: That of embryonal origin, which is supported by Schirmer,<sup>6</sup> Kraneis<sup>7</sup> (cited by Gander), and Jaulin and Grandclaude,<sup>8</sup> and that of excessive regeneration of injury (Abrikossoff,<sup>1</sup> and Gander<sup>9</sup>). Ducuing, *et al.*<sup>10</sup> even include syphilis as a possible cause. Gander goes to the point of accepting an embryonal origin for "granular cell rhabdomyoma" in all regions but the tongue, and postulates a traumatic origin of myoblastic tumors in this organ.

Horn and Stout adhere to the myogenous theory of origin, even though tumors have been reported arising in regions where no striated muscle is normally present. In such case, they assume that the lesions arise from embryonal rests of aberrant myoblastic tissue.

The reason for the indecision as regards the origin of these myoblastic lesions apparently lies in two cytologic peculiarities; one being the presence of tumor cells in regions where no striated muscle is normally found. The other reason is the occurrence of striated muscle cells which are of normal-appearing structure in one region and in others have undergone a change which strongly resembles the granular structure of the myoblastic tumor cells.

Diss,<sup>11</sup> in reporting a myoblastoma of the tongue, explains this growth in the following manner: "The muscular fibers apparently in process of undergoing granular transformation are not a part of the true tumor. These are elements which have undergone a peculiar granular degeneration, and conserve their fertility and become neoplastic. In multiplying, these granular cells conserve their characteristics, reach the mucosa, and fill its papillae."

#### SUMMARY

1. A case of myoblastoma (Abrikossoff-Type I) arising in the deep muscles of the back is reported.
2. Classification of these lesions is at present in a state of flux; a modification of that of Abrikossoff<sup>5</sup> being now most applicable.
3. Myoblastic tumors are becoming more frequently recognized.

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# BRIEF COMMUNICATION

## EPIPLOIC APPENDICITIS: A CAUSE OF LEFT-SIDED ABDOMINAL PAIN

### CASE REPORT

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THIS CASE IS REPORTED because it adds another to a list of about 62 published instances of acute inflammation of the epiploic appendages, and because the presence of nondescent of the left testicle in our patient made it necessary to consider torsion of an intra-abdominal testicle in the differential diagnosis.

**Case Report.**—Case No. 428802: D. B., male, age 31, a factory worker, was seen in the Out-patient Department, October 5, 1944. He complained of lower abdominal discomfort of three days duration, described vaguely as "gas pains." The pain became fairly well localized in the left lower quadrant. There had been no nausea or vomiting but his appetite had been poor for two days. There were no urinary symptoms.

**Physical Examination.**—The patient was moderately obese. The temperature and pulse were normal. There was exquisite tenderness in the left lower quadrant, with muscle spasm, rebound tenderness and cutaneous hyperesthesia. The left testicle was absent from the scrotum and inguinal canal; the patient stated that it had never been palpable. There were 10,200 white blood cells, 65 per cent polymorphonuclears.

The following preoperative diagnoses were considered: (1) Torsion of intra-abdominal testicle; (2) sigmoid diverticulitis; and (3) left-sided vermiform appendicitis. Dr. John K. Ormond, urologist, was consulted and he agreed that torsion of the undescended testicle was a likely diagnosis. He had seen and reported a case with this condition on the right side.<sup>8</sup>

**Operation.**—Under ethylene anesthesia, a low "left McBurney" incision was made and the peritoneal cavity was opened. Exploration encountered a firm mass which proved to be attached to the sigmoid. After some difficulty, it was delivered into the wound and it was found to consist of a markedly inflamed epiploic appendage which was attached by fibrinous adhesions to neighboring appendages. It was bluish-red in color. When the other structures had been separated from it, its attachment was found to consist of only a small pedicle. It was feared that this pedicle might contain the lumen of a diverticulum, so it was treated like the stump of the vermiform appendix by ligature and inversion. The inversion into the inflamed wall of the sigmoid was only moderately satisfactory. No mucous membrane was seen when the appendage was amputated, however.

A search was made for the missing testicle. The vas deferens was located and followed to its distal end, where a rudimentary structure was found and removed. This was done because of the known tendency of the intra-abdominal testicle to undergo malignant change. The wound was closed with drainage. The postoperative course was uneventful, and the patient was discharged on the tenth day. He returned to work in three weeks.

**Pathologic Examination.**—Dr. Frank W. Hartman: "The specimen consists of a disk of tissue, measuring 3 cm. in diameter and 1 cm. in thickness. It is covered by a serous membrane. When cut, it is seen to be composed of lobulated, reddish-gray, firm

tissue. *Microscopic*: Sections taken through the discoid piece of tissue submitted showed that it was composed of lobulated adult fat. There has been considerable extravasation of red blood cells into the intercellular tissue. Throughout the mass there are engorged vascular channels. Along one side there is a thick layer of pink-staining fibrillar tissue through which are distributed some fibroblasts and small round cells. *Impression*: Cellulitis of epiploic appendage."

COMMENT.—The correct diagnosis was not suspected preoperatively. To our knowledge, there is only one instance of a correct diagnosis. Fiske<sup>1</sup> reported that Dr. Wayne Babcock was able to do this in one case. The appendices epiploicae may have more surgical significance than is generally recognized. For further details, the reader is referred to the appended bibliography.

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## BOOK REVIEW

**ESSENTIALS OF ORAL SURGERY.** By Vilray P. Blair, M.D., and Robert K. Ivy, M.D., 3rd Edition: C. V. Mosby Co. St. Louis. 1944.

This book was originally published in 1923, of which this is the third edition. The original edition utilized much of the material from Blair's "Surgery and Diseases of the Mouth and Jaws," originally published in 1912. The present Third Edition has revised and brought up to date the chapters on wounds, shock, hemorrhage, burns and anesthesia. The section on fractures of the jaws have included some of the newer technics of fracture wiring, cast and plastic splints and the use of skeletal fixation extra oral splints.

This book has previously been used quite extensively by dental students in the colleges. The section on the extraction of teeth and especially that portion dealing with impacted teeth, could be revised and made more complete if it is to be most useful to the undergraduate or graduate dental student. The addition of a more complete bibliography would have greatly improved this edition.

This book does not pretend to be a complete text on the subject of Oral Surgery, but as its title implies, it covers the essentials. It should be a useful review of the essentials of Oral Surgery for the general practitioner and the student, and should find a place in the library of the physician and the dentist.

DOUGLAS B. PARKER, M.D.

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## OBSERVATIONS ON THE SEVERELY WOUNDED IN FORWARD FIELD HOSPITALS: WITH SPECIAL REFERENCE TO WOUND SHOCK

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AND

CAPT. FRANK WARNER, M.C., A.U.S.

DURING the first nine months of 1944, the authors were privileged to carry out a study of a clinical nature on severely wounded soldiers admitted as nontransportable to forward field hospital units. The patients had undergone a screening process at the adjacent divisional clearing stations and in the shock tents of the field hospitals. Therefore, they comprised a selected group in urgent need of resuscitation and surgical treatment. The organization of the field hospital platoon functioning as a surgical hospital a few miles behind the front was such that a competent staff and adequate facilities were at hand for resuscitation, definitive surgical operation and postoperative care. In most instances, the surgical care of the patients was in the hands of surgical teams from an auxiliary surgical group. The patients were held from one to three weeks following operation until they could be safely evacuated. It was, therefore, possible to observe the patient's condition on admission in an essentially untreated state, after restorative therapeutic measures and periodically following operation. In addition, a second and smaller group of patients suffering from severe flak wounds was studied in a station hospital immediately after return from missions over enemy territory.

### METHODS

To furnish facilities for making necessary biochemical measurements, an improvised laboratory mounted on a two and one-half ton truck (Fig. 1) was stationed at the door of the shock tent. The laboratory could be blacked out for night work and, on the whole, it proved to be a reasonably satisfactory substitute for the ordinary biochemical laboratory. The team was composed of two officers and two enlisted men, one of the latter being a biochemical technician and the other a truck driver and handy man. Since the laboratory was mobile, it could be moved to a point of greater activity when the flow of casualties fell off. Special laboratory apparatus and reagents essential for the study were obtained through the Theater Surgeon, and in various other ways.

Concentrations of hemoglobin and plasma protein, and red cell hematocrit were determined by the copper sulphate gravity method.<sup>1</sup> Normal values for the method, as obtained in a study of 42 front line soldiers with acute gonorrheal urethritis, are shown in Table II. The method proved entirely satisfactory under field conditions. The authors found that hematocrit values, as they obtained them with the method, agreed well with red cell volume as determined by centrifuging to a constant value. The ammonium and potassium oxalate mixture of Heller and Paul<sup>2</sup> was used as anticoagulant. Plasma volume was determined by Gregersen's method, using the blue dye T-1824 and the Decade Photometer devised by Nickerson<sup>3</sup> for field use. The sim-

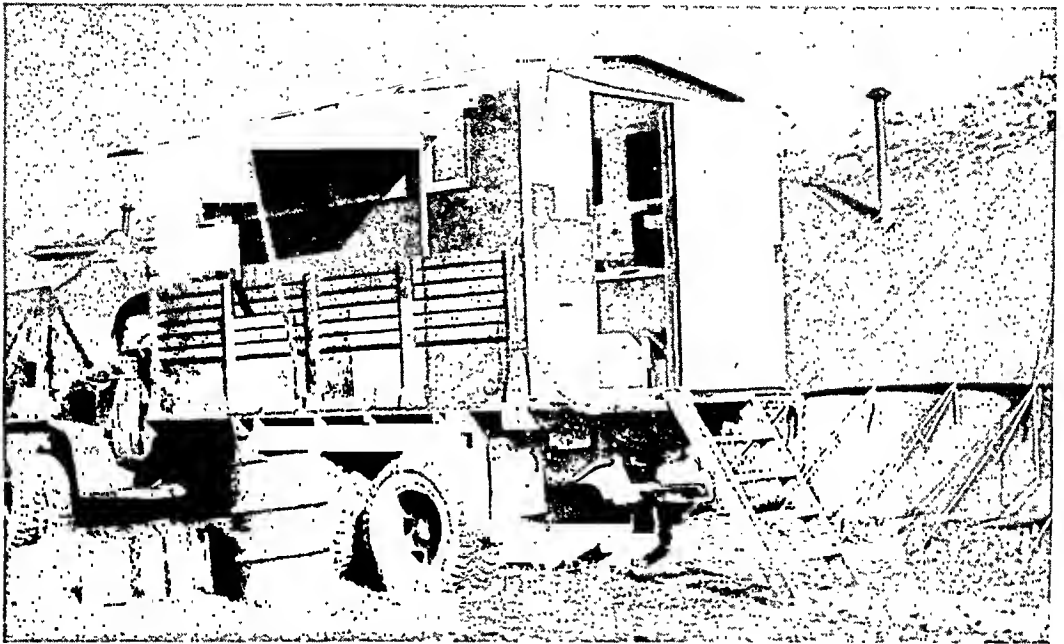


FIG. 1.—Photograph showing the two and one-half ton truck used to furnish facilities for making the biochemical measurements.

plicity, rapidity and ease of the method made it an invaluable aid, and the data obtained were of great value in controlling the intravenous therapy of hemorrhage and shock. In Table I are shown data from essentially normal ambulatory convalescent soldiers. Nonprotein nitrogen of the plasma was determined by tungstic acid precipitation of proteins followed by digestion and nesslerization.<sup>4</sup> Plasma chloride concentration was measured by the method of Wilson and Ball,<sup>5</sup> and total sulfonamide concentration by the method of Marshall and Litchfield.<sup>6</sup> Urinary ammonia was measured by digestion and nesslerization,<sup>4</sup> while titratable acidity was determined as described by Henderson and Palmer.<sup>7</sup> Analyses of the urine specimens were made daily on samples collected and stored immediately in the icebox in clean bottles containing thymol and toluol. Blood specimens were taken without stasis from vein or brachial artery. Samples were taken immediately after admission to the hospital and subsequently on a fasting basis.

CLINICAL MATERIAL AND MANAGEMENT

One hundred patients were studied in forward field hospital platoons, while a smaller group of 14 patients was seen in a station hospital receiving air combat crewmen returning from missions with severe flak wounds. All the patients had penetrating, perforating or lacerating wounds resulting from high-explosive missiles. In many instances, the wounds were multiple. It is to be emphasized that the patients were a selected group, chosen because of the extensiveness of their wounds and the presence or imminence of wound shock. All the patients were in an untreated state, practically speaking, when first seen after admission to the hospital. Splinting and bandaging, injection of morphine and tetanus toxoid, and in rare instances administration of plasma had occurred in forward aid stations or in the divisional clearing station. In many instances sulfanilamide had been applied to wounds and sulfanilamide tablets had been taken, but there were many exceptions.

All the patients were treated for shock and hemorrhage, and most of the patients were operated upon. In most instances, the nature of the wounds was such that definitive surgical operation was required, but in some cases of penetrating chest and head wounds and compound fractures, only such procedures as débridement, aspiration of hemothorax and splinting were carried out. Ether, frequently administered by endotracheal tube in a closed system, and intravenous sodium pentothal were the anesthetic agents used in most cases. None of the patients suffered from burns. However, for purposes of contrast, one burn case is considered in Table XXV but is in no other way included in the study. Plasma and blood were freely used in resuscitation and during operation, and to some extent postoperatively. Penicillin was given as a rule only in the treatment of infection but some of the patients during the latter part of the study were given 150,000 to 200,000 units daily as a routine measure during the first week after admission to hospital.

The severity of the wounds is attested by the high percentage of compound fractures, penetrating abdominal wounds and penetrating chest wounds, as shown in Tables IV, V and VI. Nevertheless, during the period of observation, varying from two or three days to four or five weeks, there were only 17 deaths out of the 100 patients admitted to the field hospitals, and two deaths among the 14 patients with flak wounds admitted to a station hospital. The difficulties of the terrain and the resultant problem in evacuation of the wounded are brought out in an analysis of the time factors, as shown in Table III. The average time from wounding to tagging and from tagging to admission to a field hospital are the significant figures. The average interval between admission to hospital and surgical operation, which was 3.5 hours, is a measure of the thoroughness of preoperative care, for at no time was there delay due to lack of facilities or surgical personnel. One of the patients in the group of 100 ground force casualties died after admission to hospital without responding sufficiently to restorative measures to permit operation.

On admission to the field hospital, the patients were triaged in the shock tent by the surgeon on call. As a rule, resuscitation was supervised by the surgeon who was to operate, and he it was who decided when the patient was in suitable condition for operation, sometimes a very difficult question. Postoperative care, likewise, was the responsibility of the operating surgeon, and, on the whole, this was conscientiously and skillfully attended to. For the most part, standard principles of war surgery were adhered to at operation. At celiotomy, exteriorization or resection of wounded small intestine was avoided wherever possible; wounded colon was exteriorized; liver wounds were usually packed with the end of a Penrose drain, though suture was sometimes performed; the damaged spleen was removed and the wounded kidney was resected or removed if required; suprapubic cystostomy was practiced in perforations of the bladder; thoracotomy was performed in cases of penetrating chest wounds in the presence of continued bleeding or uncertainty as to the extent of mediastinal or subdiaphragmatic trauma. In some instances upper abdominal surgery was done by the thoracic transdiaphragmatic approach. Large collections of blood in the pleural cavity were aspirated and aspiration or catheter drainage was the usual treatment for tension pneumothorax. Sucking wounds of the chest were closed as simply as possible by pressure dressing, or by suture of pleura and muscle or fascia with superficial drainage. Compound fractures were treated by débridement and plaster splinting, or by guillotine amputation if the extent of tissue loss so indicated.

Postoperative care was characterized by the free use of oxygen therapy, the administration of plasma, blood, glucose and saline intravenously, nasogastric continuous suction when needed, the intravenous administration of sodium sulfadiazine in most abdominal cases in addition to the application of sulfanilamide to the wounds. Nursing care was of a high quality and contributed greatly to the successful management of the cases.

In Table IX are noted pertinent data from the 17 instances in which death occurred among the 100 cases observed in field hospitals. Autopsy was performed in every instance, but only the gross pathologic findings can be reported. The incidence of clostridial infection, pulmonary thrombo-embolism, peritonitis, aspiration pneumonia, blast injury and irreparable shock are notable.

The variability in the clinical picture of wound shock was rather striking, and gave the impression that the usual concepts in the definition of traumatic shock are too rigid. The mental and emotional state of the patient, pain, blood pressure, pulse rate, sweating, nausea and vomiting, extent of filling of peripheral veins, skin temperature and plasma volume all were elements subject to considerable variation. It was clear that no single factor could be used in setting up a criterion for gauging the severity of shock, or the efficacy of restorative measures. Perhaps the most constant feature of the compensatory reactions in severe wound shock was the delicacy of the balance achieved and the rapidity with which a precarious adjustment could be improved or made worse. In illustration of this point the relationship between

systolic blood pressure and pulse rate should be mentioned. If these two factors are plotted together a rough inverse proportionality is detected, but exceptions are common, and low systolic blood pressure may be found with a normal pulse rate and normal or high blood pressure with a rapid pulse. Table XI contains pertinent data. It was frequently observed that patients brought into the shock tent without detectable peripheral blood pressure or pulse, after resting a few minutes under blankets in the head-down position and after receiving only an ounce or two of plasma, showed great improvement with normal or near-normal blood pressure and pulse.

#### PRESENTATION OF DATA AND DISCUSSION

From Table X, it is apparent that reduction in plasma volume was the rule in the severely wounded before replacement therapy. This was rapidly corrected through natural adjustments and by parenteral fluid therapy. The data, weight and surface area could not be obtained in these patients, so there is only the unreliable figure of last-remembered weight to refer plasma volume to. There were enough cases under examination, however, so that average values can be used to set up standard figures. The volume of the whole blood was proportionately more depleted than that of the plasma, as analysis of the changes in hematocrit and plasma protein concentration will show. If the average values for plasma volume, plasma protein concentration and hematocrit during the first 24 hours are compared with those for the second period (one to four days), it is evident that an increase in blood volume was effected despite a reduction in concentration of both hemoglobin and plasma protein. If total circulating hemoglobin and plasma protein are computed at the two periods, it can be seen that initial deficits of hemoglobin are relatively greater than deficits of plasma protein and are less easily corrected. The validity of this observation is somewhat depreciated by the uncertain effects of plasma infusion and blood transfusions during the periods considered. With respect to administration of plasma and whole blood, it was repeatedly noted that quantitative changes do not result from such therapy. These observations lead to provocative questions, but one obvious explanation is that depleted storehouses for plasma protein and hemoglobin have a high priority during restorative therapy. The data shown in Tables XVI to XXIV, inclusive, bear on this point.

Hemoconcentration, either of red cells or plasma protein, was conspicuously absent even in the cases seen quite early after severe wounding. The one case of severe burn (Table XXV) is inserted for contrast. All these patients were gravely wounded, some were in a state of irreparable traumatic shock, and yet in every instance the initial measurements before treatment disclosed either normal or, much more commonly, reduced hemoglobin and plasma protein values. Loss of blood into tissues, body cavities and to the outside dominated the picture and clearly afforded the clue to proper resuscitation. In considering average plasma protein values for the various periods, as seen in Table X, at no time was the average below the range of

TABLE I

PLASMA VOLUME DETERMINATIONS; 53 MEASUREMENTS ON 29  
AMBULATORY CONVALESCENT SOLDIERS

	Cc.	Cc./Kg.
Average.....	3290	45
High.....	4650	57
Low.....	2450	38

TABLE II

VALUES FOR HEMATOCRIT AND PLASMA PROTEIN CONCENTRATION  
BY  $\text{Cu SO}_4$  GRAVITY METHOD AS DETERMINED ON 42 FRONT-LINE  
SOLDIERS WITH GONORRHEA

	Hematocrit %	Plasma Protein Gm/100/cc.
Average.....	43.3	7.0
High.....	50.5	8.0
Low.....	37.5	6.2

TABLE III

TIME RELATIONSHIPS IN MEDICAL CARE AFTER SEVERE WOUNDING; 100 GROUND FORCE  
CASUALTIES ADMITTED TO FORWARD FIELD HOSPITAL PLATOONS

	Average Hours	Minimum Hours	Maximum Hours
Time, wounding to tagging.....	1.80	0.10	18.00
Time, wounding to admission to hospital...	4.90	0.60	25.20
Time, wounding to operation.....	8.45	2.75	26.00

TABLE IV

COMPOUND FRACTURES AS RECEIVED BY 55 OUT OF 100 GROUND  
FORCE CASUALTIES WOUNDED BY HIGH EXPLOSIVE MISSILES  
INCLUDING "TRAUMATIC AMPUTATION" IN 17

Femur.....	13
Tibia.....	12
Feet.....	9
Fibula.....	7
Ulna.....	5
Humerus.....	4
Ribs.....	4
Skull.....	4
Spine.....	3
Radius.....	3
Hand.....	3
Pelvis.....	2
Scapula.....	2
Clavicle.....	1

TABLE V

PENETRATING ABDOMINAL WOUNDS AS RECEIVED BY 48 OUT OF  
100 GROUND FORCE CASUALTIES WOUNDED BY HIGH EXPLOSIVE  
MISSILES; VISCERA WOUNDED

Colon.....	23
Small intestines.....	21
Liver.....	14
Stomach.....	10
Spleen.....	7
Kidney.....	6
Duodenum.....	4
Rectum.....	2
Bladder.....	1

WOUND SHOCK IN FIELD HOSPITALS

TABLE VI

WOUNDS AS RECEIVED BY 100 GROUND FORCE CASUALTIES FROM  
HIGH EXPLOSIVE MISSILES, SEEN IN FORWARD FIELD HOSPITAL  
PLATOONS

Compound fractures.....	55
Penetrating abdominal wound.....	48
Penetrating thoracic wound.....	32
Penetrating abdominothoracic or abdominal and thoracic .	19

TABLE VII

WOUNDING AGENT IN 100 GROUND FORCE CAUSALTIES FROM  
HIGH EXPLOSIVE MISSILES

Shell fire.....	80
Mine.....	8
Grenade.....	6
Bullet.....	5
Aerial bomb.....	1

TABLE VIII

PLASMA AND BLOOD TRANSFUSIONS DURING FIRST 24 HOURS AFTER ADMISSION TO FORWARD HOSPITAL FOLLOWING  
SEVERE WOUNDING—87 PATIENTS. IN EIGHT CASES NEITHER BLOOD NOR PLASMA WAS GIVEN DURING THE PERIOD.

Plasma Therapy			Blood Therapy		
Average	High	Patients	Average	High	Patients
720 cc.	2500 cc.	Receiving None	1130 cc.	4000 cc.	Receiving None
		10			28

TABLE IX

DEATHS OCCURRING IN 100 SEVERELY WOUNDED GROUND FORCE CASUALTIES ADMITTED TO FORWARD  
FIELD HOSPITALS

Case Number	Survival Period—Days	Autopsy Findings and Clinical Diagnosis
6	2	Abdominothoracic wounds, perforation of the esophagus; shock and hemorrhage
8	1	Perforating abdominal wound, compound fracture of femur; severe shock
9	1	Blast injury both lungs, compound fracture of clavicle, lacerations of chest wall
10	4	Penetrating wounds of abdomen and brain, traumatic amputation of foot massive, bilateral pulmonary infarcts
16	36	"Traumatic amputation" of thigh, clostridial myositis, massive empyema
21	4	Penetrating abdominal wound, perforation of colon, ileum, kidney; pulmonary embolism
25	1	Perforating wound of mediastinum, aspiration of vomitus during anesthesia; died at operation
26	1	Penetrating wound of abdomen, perforation of ileum, colon, rectosigmoid; aspiration of vomitus during anesthesia; acute dilation of stomach
27	3	Penetrating abdominal wound, perforation of liver, stomach, jejunum; resection of jejunum; fibrinous peritonitis, edema of lungs
28	12	Penetrating abdominal wound, perforation of colon and jejunum, "traumatic amputation" of thigh, perforating wound of buttocks; clostridial myositis, broncho-pneumonia
32	5	Penetrating thoraco-abdominal wounds, perforation of colon, small intestine; "retroperitoneal cellulitis with gas formation"
33	1	Penetrating thoraco-abdominal wound, abdominal evisceration; severe shock
38	1	Penetrating wounds of chest, abdomen, thigh, perforation of colon, feculent peritonitis
39	13	Penetrating wound of chest, laceration of thigh; retroperitoneal infection; "blast injury" of heart and lungs; multiple pulmonary emboli
61	1	Penetrating abdomino-thoracic wounds, perforation of liver, spleen, stomach; severe shock; death at operation
65	1	Multiple penetrating wounds of abdomen and chest; severe shock; died before operation
111	4	Penetrating wounds of abdomen, perforation of colon, acute dilatation of stomach, bilateral pneumonia



TABLE X

PLASMA PROTEIN AND HEMATOCRIT VALUES AT VARYING INTERVALS AFTER SEVERE WOUNDING; INITIAL DETERMINATIONS MADE BEFORE RESUSCITATION—87 PATIENTS

Interval Days, Inclusive	Plasma Protein, Gm./100 Cc.				Hematocrit, %				Plasma Volume, Cc.			
				No. of Observations				No. of Observations				No. of Observations
	Avg.	High	Low		Avg.	High	Low		Avg.	High	Low	
Initial.....	6.47	7.5	5.1	71	37.5	60.0	17.0	86	2950	4250	1030	84
1-4.....	6.30	7.7	4.6	114	34.5	48.5	23.0	102	3470	4650	2700	44
5-8.....	6.32	7.7	4.5	50	33.6	46.0	19.5	50	3290	3750	2850	7
9-12.....	6.41	7.4	5.1	33	36.3	48.2	26.5	33	3480	4450	2850	12
13 plus.....	6.55	8.2	4.8	9	39.8	50.5	30.5	22	3400	4100	2900	7

TABLE XI

DATA ON WOUNDED GROUPED ACCORDING TO BLOOD PRESSURE; MEASUREMENTS ON ADMISSION TO HOSPITAL BEFORE RESUSCITATION

		Blood Pressure				Plasma	Plasma	Hemat-	Infusions Be- fore and Dur- ing Operation	
		Syst.	Diast.	Pulse P.	Pulse Rate	Volume Cc.	Protein Gm./100Cc.	ocrit %	Plasma Cc.	Blood Cc.
Systolic B.P. zero	Average					2490	6.12	37.9	620	1340
12 cases (5 deaths)	High				140	3300	7.30	56.0	1250	4000
	Low				120	1030	5.10	31.4	250	0
Systolic B.P. less than	Average	85	47	38	122	2890	6.34	36.8	840	1220
100	High	98	70	88	160	4400	7.50	60.0	2000	3000
39 cases (9 deaths)	Low	38	20	18	80	1250	5.50	17.0	0	0
Systolic B.P. 100 or	Average	120	69	52	102	2960	6.43	38.4	620	920
over	High	154	104	108	148	4250	7.50	49.7	2500	2000
36 cases (4 deaths)	Low	102	30	27	80	1820	5.60	26.0	200	0

TABLE XII

DATA ON WOUNDED GROUPED ACCORDING TO PLASMA VOLUME; MEASUREMENTS ON ADMISSION AND BEFORE RESUSCITATION

		Blood Pressure				Plasma Volume Cc.	Plasma Protein Gm.%	Hemat- ocrit %	Infusions Be- fore and Dur- ing Operation	
		Syst.	Diast.	Pulse P.	Pulse Rate				Plasma Blood	
Cases with PV of 2700 or below (33 cases, 10 deaths)	Average	99	58	41	112	2200	6.25	37.2	640	1090
	High	140	104	72	156	2700	7.2	56.0	1500	4000
	Low	0	0	0	80	1030	5.1	17.0	170	250
PV of 2701 to 3200 inclusive (30 cases, 6 deaths)	Average	89	55	44	112	2950	6.43	36.6	860	1070
	High	154	80	108	148	3200	7.5	45.0	2500	2500
	Low	0	0	0	84	2700	5.5	26.0	200	350
PV of 3201 or above (24 cases, 2 deaths)	Average	105	62	42	108	3640	6.45	38.4	660	1130
	High	138	84	88	140	4400	7.5	60.0	1125	3000
	Low	0	0	0	74	1300	5.6	28.0	200	500

TABLE XIII

DATA ON WOUNDED GROUPED ACCORDING TO HEMATOCRIT (VC); MEASUREMENTS ON ADMISSION AND BEFORE RESUSCITATION

BEFORE RESECTION									Infusions Be- fore and Dur- ing Operation	
		Blood Pressure				Plasma Volume	Plasma Protein	Vc.	Plasma	Blood
		Syst.	Diast.	P.	Pulse Rate	Cc.	Gm.%	%	Cc.	Cc.
Cases with Vc 35.0 or below (24 cases, 3 deaths)	Average	95	53	44	116	2815	5.99	31.0	950	1130
	High	154	80	88	156	3500	6.8	35.0	2500	2000
	Low	0	0	0	74	2050	5.5	17.0	250	350
Cases with Vc 35.1 to 40.0 inclusive (39 cases, 9 deaths)	Average	96	59	40	112	2900	6.27	37.7	670	1050
	High	138	104	88	160	4400	7.5	40.0	2000	3000
	Low	0	0	0	80	1030	5.1	35.4	200	250
Cases with Vc 40.1 or higher (24 cases, 6 deaths)	Average	103	62	44	109	2864	6.63	44.5	560	1070
	High	140	99	108	160	4100	7.5	56.0	1000	2000
	Low	0	0	0	80	1820	5.6	40.5	100	500

# WOUND SHOCK IN FIELD HOSPITALS

TABLE XIV

MEASUREMENTS OF PLASMA NONPROTEIN NITROGEN CONCENTRATIONS AT VARYING INTERVALS AFTER SEVERE WOUNDINGS IN 95 GROUND FORCE CASUALTIES TREATED IN FORWARD FIELD HOSPITAL PLATOONS; VALUES EXPRESSED IN MG./100 CC.

	1st Day	2-3 Days	4-6 Days	7-12 Days	13-21 Days
Average.....	30.8	37.6	44.1	50.2	30.9
High.....	64.5	102.0	115.0	125.0	94.0
Low.....	14.8	19.8	20.4	18.2	21.4
No. of observations.....	67	55	31	23	14

TABLE XV

WHOLE BLOOD TOTAL SULFONAMIDE CONCENTRATION IN 89 GROUND FORCE BATTLE CASUALTIES AT VARYING INTERVALS AFTER SEVERE WOUNDING; ALL PATIENTS HAD RECEIVED SULFONAMIDE TOPICALLY, ORALLY, OR PARENTERALLY; VALUES EXPRESSED IN MG./100 CC.

	Period, Days After Wounding					
	1	2	3	4-6	7-10	11-21
Average value, cases with positive tests.....	3.6	7.5	7.8	8.6	6.7	5.1
Highest value for period.....	6.5	20.0	25.0	25.0	15.0	13.2
Cases with values above 12.0 mg. %.....	0	4	7	8	3	1
Number of cases with positive tests.....	5	24	37	43	36	35
Number of cases with negative tests.....	53	12	6	4	11	24
Total number of cases.....	58	36	43	47	47	59

TABLE XVI

CASE 31: SHELL FRAGMENT WOUND, PENETRATING RIGHT HEMOTHORAX, DIAPHRAGM AND KIDNEY; LACERATION OF LIVER. CELIOTOMY

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid
2/4	1100	Wounded										
	1115	Tagged										
	1145	Admitted to field hospital								150		
	1209	Blood studies	6.7	39.1	13.2	2900	26.8		0			
	1630	Operation								500	500	1000
2/5		Severe chill following transfusion									500	
2/6	0700	Blood studies	6.5	44.0	14.7				8.7			1300
2/8	0713	Blood studies	6.2	42.0	14.2		38.2		4.4			1000
2/10	0715	Blood studies	6.3	38.5	13.0				2.7			
2/12	0730	Blood studies	7.3	41.0	13.8				8.5			
2/14											500	
2/15	0730	Blood studies	7.2	39.5	13.3				4.0			
2/17	0747	Blood studies	6.8	39.5	13.4	3200	29.3		5.3			
2/19	0720	Blood studies	6.7	38.5	13.0				4.2			
2/21	0745	Blood studies	6.7	37.5	12.6				0			
2/23	0740	Blood studies	6.7	38.5	13.0				3.1			
2/25	0731	Blood studies	6.3	38.0	12.9	3150	21.5	92.5	5.5			
		Evacuated										

Patient's weight—165 lb. (August, 1943). Height—66 inches.

On admission to hospital patient's condition was fairly good: B. P.—102/75, P.—84.

Chemotherapy: 4 Gm. sulfanilamide orally after wounding, 5.0 Gm. sulfanilamide into wounds at operation, 75.5 Gm. sulfadiazine or sod. sulfadiazine orally or I.V. through 2/25.

PP equals plasma protein in Gm. per 100 cc.; Vc equals red cell hematocrit in percentage; Hb equals hemoglobin in Gm. per 100 cc.; PV equals plasma volume in cc.; NPN equals plasma nonprotein nitrogen in mg. per 100 cc.; Cl equals plasma chloride in milli-equivalents per liter; sulfa equals blood total sulfonamide in mg. per 100 cc.; I.V. therapy equals intravenous infusions in cc. of plasma, blood or 5% glucose in saline solution.

TABLE XVII

CASE 30: SHELL FRAGMENT WOUND, PENETRATING LUNG, DIAPHRAGM, SPLEEN.  
THORACOTOMY, CELIOTOMY, SPLENECTOMY.

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	VC	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid
2/11	1330	Wounded										
	1340	Tagged										
	1410	Admitted to field hospital								400		
	1448	Blood studies	6.0	34.0	11.4	2400	22.8		0			
	1730	Operation								150	1500	
2/12										500		3000
2/13	0730	Blood studies	6.0	37.5	12.4				4.8			
2/14											500	
2/15	0709	Blood studies	5.6	37.0	12.3	3300	25.0		4.4		500	
2/17	0730	Blood studies	6.5	40.5	13.7				2.6			
2/19	0715	Blood studies	6.5	40.5	13.6				5.8		500	
2/21	0730	Blood studies	6.7	43.5	14.7				6.7			
2/22	0717	Blood studies	7.0	45.5	15.4		29.1	96.7	tr			
2/24	0715	Blood studies	6.8	44.0	14.8				6.3			
2/25		Evacuated										

Patient's weight 140 lbs. (February, 1943). Height—67 inches.

On admission to hospital B.P. was 118/80, skin was ashen and cold. During operation B.P. dropped to 70/52, P. 144.

Chemotherapy: 37.5 Gm. sod. sulfadiazine or sulfadiazine given I.V. or P.O. through 2/24. (See Table XVI for legend)

TABLE XVIII

CASE 39: SHELL FRAGMENT WOUND, PERFORATION OF THORAX AND RETROPERITONEAL REGION, LACERATIONS  
RIGHT THIGH; TRAUMATIC SHOCK; THORACOTOMY AND DÉBRIDEMENT; DEATH

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid
2/14	1740	Wounded										
	1815	Tagged								750		
	2115	Admitted to field hospital										
	2127	Blood studies	5.6	35.4	12.0	2700	29.2		0			
	2300	Operation								500	500	
2/15												2000
2/16	0730	Blood studies	5.5	32.5	11.0				tr.			
2/17	0712	Blood studies	5.7	32.0	10.8	3100	37.5		1.8			1200
2/19	0715	Blood studies	4.8	24.5	8.2				11.1	500	500	1000
2/21	0730	Blood studies	4.5	34.0	11.5				9.3		500	
2/23	0700	Blood studies	5.5	34.5	11.7				8.4			
2/25	0706	Blood studies	5.6	38.5	13.2	3300	25.1		7.8	250	500	
2/27	0730	Blood studies	4.8	47.5	16.1			95.8	5.9	250	1000	2000
	1535	Death										

On admission to hospital, the patient's B.P. was 0/0, pulse not palpable.

Sulfonamide therapy: 2.5 Gm. sulfanilamide taken orally after wounding; 5.0 Gm. sod. sulfadiazine given I.V. daily.

Autopsy: Severe retroperitoneal sepsis, infected wounds of left thigh, multiple pulmonary infarcts, blast injury of heart and lungs, hemothorax, rt.

Weight: 158 lbs. (April, 1943). Height—67 inches. (See Table XVI for legend)

# WOUND SHOCK IN FIELD HOSPITALS

TABLE XIX

CASE 51: PERFORATING GUNSHOT WOUND OF UPPER ABDOMEN THROUGH LIVER, COLON; TRAUMATIC SHOCK; CELIOTOMY, SUTURE OF LIVER, EXTERIORIZATION OF COLON

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid
4/20	0600	Wounded										
	0700	Tagged								750		
	0820	Admitted to field hospital										
	0844	Blood studies	6.5	35.0	11.9	2950	23.5	101.0	0			
	1130	Operation									1500	1000
												1000
4/21	0730	Blood studies	6.3	45.5	15.5				11.4			2000
4/22	0726	Blood studies	6.3	35.0	11.8	3750	29.6	104.4	5.1	250		2000
												2000
4/24	0715	Blood studies	7.6	30.0	10.3				7.9			1000
4/26	0740	Blood studies	6.3	31.0	10.4				4.8			
4/28	0715	Blood studies	6.3	33.5	11.2				4.2			
4/30	0715	Blood studies	6.5	29.5	10.1				7.5			
5/2	0735	Blood studies	7.2	33.0	11.1				3.6			
5/3	0735	Blood studies	7.3	34.5	11.3				6.1			
5/5	0730	Blood studies	7.0	35.0	11.8				10.0			
5/7	0735	Blood studies	6.7	33.0	11.1				8.3			
5/9	0735	Blood studies	6.7	34.5	11.6				9.4			
		Evacuated										

On admission to field hospital, B.P. was 124/72 (after 750 cc. plasma), skin was moist, mind was clear.

Sulfonamide therapy: 7.5 Gm. sulfanilamide into wounds at operation; 70.5 Gm. sodium sulfadiazine given I.V. in daily doses 4/21 to 5/9.

Weight—175 lbs. (September, 1943). Height—68 inches. (See Table XVI for legend)

TABLE XX

CASE 27: SHELL FRAGMENT WOUND, PENETRATING ABDOMEN, WITH PERFORATION OF STOMACH, JEJUNUM AND LIVER. CELIOTOMY RESECTION OF JEJUNUM, SUTURE OF STOMACH AND LIVER. POSTOPERATIVE OLIGURIA; DEATH

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Urine Fluid Volume
2/21	1500	Wounded										
	1525	Tagged										
	1710	Admitted to field hospital								750		
	1738	Blood studies	6.8	41.5	14.0	3350	22.2	97.6	tr.			
	1825	Operation								1000	2000	
2/22	0740	Blood studies	5.0	42.0	14.2				18.8			2000 250
												2000
2/23	0657	Blood studies	6.3	40.5	13.7	3600	88.2	99.3	19.4			1000 550
	2330	Blood studies										
2/24	0740	Blood studies	6.0	39.5	13.3		94.0	107.0	11.7	250	500	2000 ?
	1600	Venesection, 500 cc.										
	1910	Death										

On admission to hospital, patient's B.P. was 130/75, P. 140; occasional vomiting.

During operation B.P. was unstable and at one time dropped to 70/40.

Sulfonamide therapy: 2.5 Gm. sulfanilamide taken by mouth after wounding, 5 Gm. sod. sulfathiazole given I.V. after operation, 10 Gm. sulfanilamide put into peritoneal cavity at operation.

Autopsy: Engorgement of abdominal viscera, fibrinous peritonitis, edema of both lungs, serosanguineous bilateral pleural effusion, cloudy swelling of both kidneys.

Weight—170 lbs. (February, 1943). Height—73 inches. (See Table XVI for legend)

TABLE XXI

CASE 66: SHELL FRAGMENT WOUND, PENETRATING CHEST, ABDOMEN; PERFORATION OF COLON, SPLEEN, KIDNEY, SMALL INTESTINES; SPLENECTOMY; TRAUMATIC SHOCK; POSTOPERATIVE OLIGURIA AND RENAL INSUFFICIENCY; RECOVERY

Date	Time	Remarks	Blood Values							I. V. Therapy			
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid	Urine Volume
5/3	0635	Wounded											
	0640	Tagged											
	0925	Admitted to field hospital B.P. 0/0, P. 140								250			
	0931	Blood studies	6.5	35.0	12.0	2150	33	101.9	0				
	1300	Operation								250	1000		
5/4	0735	Blood studies	7.2	48.5	16.5				18.1		1000	1000	
												1000	160
5/5	0648	Blood studies	6.1	44.0	14.9	3200	102	100.2	25.0			2000	700
5/6	0735	Blood studies	6.3	32.5	11.0		115		25.0			1000	1800?
5/7	0725	Blood studies	7.0	32.0	10.6		116		21.7		500	1700	700?
5/8	0700	Blood studies	7.0	39.5	13.2		124	95.4	10.7			3500	2245
5/9	0715	Blood studies	7.7	40.0	13.4		118	102.3	5.4		500	1000	2375
5/10	0730	Blood studies					125	102.2			500	1000	?
5/11	0745	Blood studies	7.7	46.0	15.5				3.5			1000	?
5/12	0759	Blood studies	7.0	39.0	13.2	2850	94	101.9	tr.				?
5/13		Evacuated											

Weight—140 lbs. (Sept., 1944). Height—64 inches.

On admission to field hospital B.P. 0/0, P (carotid) 140, skin cyanotic but dry, responded slowly but intelligently to questioning. Normal wt. 120 lbs., last wt. Sept., 1943, 140 lbs., height, 64 inches.

Sulfonamide therapy: sulfanilamide in wound dressing, no tablets taken; 20 Gm. to peritoneum at operation, 5 Gm. sod. sulfadiazine I.V. at conclusion of operation.

Urine: 5/4: sp. gr. 1.014, albumin plus plus, loaded with red cells, many granular casts.

5/7: sp. gr. 1.014, albumin plus plus plus, acid, loaded with red cells.

5/9: yellow, acid, sp. gr. 1.015, albumin plus plus plus, occasional red blood cell, occ. white blood cell.

Blood pressure: 5/7—165/82, 5/8—200/90.

Special medication: 5/5: 150 cc. 10%  $MgSO_4$  plus 500 cc. 0.5% KCl I.V.

5/6: KCl 6.25 Gm. IV.,  $MgSO_4$  10 Gm. I.M. and 20 Gm. I.V. (See Table XVI for legend)

TABLE XXII

CASE 45: SHELL FRAGMENT WOUND, COMPOUND FRACTURE OF FEMUR AND AVULSION OF THIGH; PROBABLE RENAL DAMAGE

Date	Time	Remarks	Blood Values							I.V. Therapy			
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid	Urine Volume
4/24	0545	Wounded											
	0630	Tagged											
	0700									2500			
	1300												
	1530	Admitted to field hospital											
	1536	Blood studies	6.6	26.0	8.9	2900	47	97.2	3.0				
											1500	250	
	1910	Blood studies	7.0	32.5	11.0								
	1920	Operation started									1000	500	
	2130	Blood studies	6.0	30.0	10.2							500	
4/25	0730	Blood studies	6.3	27.1	9.2				13.6	500		1000	
4/26	0706	Blood studies	5.6	23.5	8.0	3050	75	94.7	12.8	500		750	1200
4/27	1000	Blood studies					83				1500	1000	2450
4/28	0715	Blood studies	6.2	31.0	10.3		85		4.9		1000		1990
4/29	0715	Blood studies	6.5	38.0	12.9		91	100.7	4.6		1000		1700
4/30	0715	Blood studies	6.7	43.0	14.3		96		2.9				1700
5/1	1000	Blood studies	6.8	44.0	14.9		100		2.0		500		2650
5/2													2350
5/3	0725	Blood studies	6.7	41.5	14.0		66		tr.				2490
5/4	0710	Blood studies	6.8	42.0	14.2	3450	62	106.6	3.8				
		Evacuated											

On admission to field hospital: B.P. 124/44, P 104, BP remained up.

Sulfonamide therapy: 4.0 Gm. sulfanilamide orally after wounding; 15.0 Gm. in wound at operation.

4/26 Urine: sp. gr. 1.012, PH 8.0, albumin plus, epithelial cells and coarsely granular casts.

4/28 Urine: sp. gr. 1.010, PH 7.0, albumin plus, occ. W.B.C.

4/30 Urine: sp. gr. 1.010, PH 4.0, albumin plus, occ. W.B.C.

Patient's weight—145 lbs. for past 3-4 years; last weighed Sept., '43. Height—67.5 inches.

(See Table XVI for legend)

## WOUND SHOCK IN FIELD HOSPITALS

TABLE XXIII

CASE 16: SHELL FRAGMENT WOUND OF BOTH THIGHS, COMPOUND FRACTURE OF LEFT FEMUR; AMPUTATION LEFT THIGH, CLOSTRIDIAL MYOSITIS OF THIGH PENICILLIN THERAPY

Date	Time	Remarks	Blood Values							I.V. Therapy	
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood
1/22	0430	Wounded									
	0530	Tagged									
	0710	Admitted to field hospital, B.P. 126/74, P. 156								500	1000
	1030	Operation									2000
1/25	0600	Peripheral vascular col- lapse, clostridial myositis									
	1700	Blood studies	5.6	32.0	11.0				1.8		
1/28	1000	Blood studies. Extensive wound edema	5.0	53.0	17.8					1000	
2/2	0700	Blood studies	4.6	43.5	14.8	1540	33.9		0	500	500
2/4	0737	Blood studies	5.5	35.0	11.8	2300	24.4		0		
2/7	0700	Blood studies	4.6	29.1	10.0				0		
2/9	0815	Blood studies	5.5	36.0	12.2				tr.		
2/10	0730	Blood studies	5.1	34.5	11.8				1.5		
2/13	0745	Blood studies	6.0	42.0	14.2				tr.		500
2/16	0800	Blood studies	6.0	45.0	15.2				0	500	500
2/19	0720	Blood studies	6.2	44.5	15.1				0		500
2/22	0750	Blood studies	6.0	47.5	16.2				0		
2/25	0755	Blood studies	6.5	46.8	15.8				0		
2/26	0638	Blood studies. Evacuated	6.3	45.5	15.3	2850	20.0	87.0	0		

Development of clostridial myositis in thigh amputation stump heralded by sudden peripheral vascular collapse; edema and muscle necrosis followed.

Chemotherapy: 5 Gm. sulfanilamide taken by mouth after wounding. Penicillin (200,000 units per day), sulfathiazole (4 Gm. per day) from 28 January to 21 February. Gas antitoxin given at onset of infection.

Outcome: Condition improved steadily until after evacuation; death subsequently from undetected extensive empyema.

Weight—136 lbs. Height—67 inches. (See Table XVI for legend)

TABLE XXIV

CASE 28: SHELL FRAGMENT WOUNDS, MULTIPLE, PENETRATING ABDOMEN, JEJUNUM. COLON, BUTTOCKS; AMPUTATION OF LEFT THIGH; TRAUMATIC SHOCK; CLOSTRIDIAL MYOSITIS IN THIGH WOUND; DEATH DESPITE PENICILLIN THERAPY

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid
2/12	0700	Wounded										
	0845	Tagged										
	1910	Admitted to field hospital; B.P. 98/60, P. 128								1500		
	1931	Blood studies	6.3	28.5	9.8	3200	34.9		0	500	1000	
2/13	0300	Operation. Clostridial my- ositis of thigh suspected Severe postop. hemor- rhage from thigh stump									1000	
2/14	0730	Blood studies	6.7	30.5	10.3		30.0		12.6	250	500	1000
2/15											500	4000
2/16	0752	Blood studies	5.6	32.0	10.8	3125	30.0		tr.			2000
2/17												2000
2/18	0740	Blood studies	5.0	34.5	11.8				tr.			1000
2/20	0730	Blood studies. Extensive edema of trunk	4.8	31.5	10.7				tr.			
2/22	0730	Blood studies	4.8	36.5	12.3				4.0			
2/24	0530	Died										

Clostridial myositis of amputation stump suspected initially at operation from odor and appearance of wound. Penicillin therapy started (120,000 units daily) and continued until death. Sod. sulfadiazine started I.V. 2/14 at rate of 2.5 Gm. daily.

Autopsy: Anaerobic infection (probably clostridial myositis) of buttocks and thigh amputation stump; partial pulmonary atelectasis and early pneumonia of right lower lobe. Peritoneal cavity clean.

Weight—140 lbs. (February, 1943). (See Table XVI for legend)

TABLE XXV

CASE 64: BURNS, GENERALIZED, SECOND AND THIRD DEGREE, FROM EXPLOSION OF FLAME THROWER. DEATH

Date	Time	Remarks	Blood Values							I. V. Therapy		
			PP	Vc	Hb	PV	NPN	Cl	Sulfa	Plasma	Blood	Other Fluid
5/11	0920	Burned										
	0930	Tagged										
	1220	Admitted to field hospital								1375		
	1252	Blood studies	7.3	59.0	20.0	2250	35.1	98.6	0			
	1330	Surgical dressing								2150		1000
5/12	0700	Tracheotomy										
	1000	Death										

On admission to hospital the B.P. was 128/98, P. 112, respirations 9. The patient answered questions intelligently and quickly but spoke in a whisper. The blood at venepuncture was dark and viscous.

Autopsy: Diffuse capillo-venous engorgement of pulmonary tissue, acute tracheobronchitis and laryngitis with fibrinous exudate.

Weight—190 lbs. (3 months ago). Height—70 inches. (See Table XVI for legend)

TABLE XXVI

OBSERVATIONS ON THE SPECIFIC GRAVITY OF FRESHLY VOIDED URINE OF SEVERELY WOUNDED SOLDIERS

	1st Day	2nd Day	3rd Day	4th Day
Number of samples voided.....	108	84	58	26
Number of patients.....	20	19	15	6
Average specific gravity.....	1.021	1.020	1.020	1.020
Highest specific gravity.....	1.033	1.032	1.034	1.030
Lowest specific gravity.....	1.001	1.003	1.004	1.007

TABLE XXVII

OBSERVATIONS ON THE REACTION OF FRESHLY VOIDED URINE (USING NITROZINE PAPER) OF SEVERELY WOUNDED SOLDIERS; NONE HAD  $\text{NaHCO}_3$  THERAPY

Day	1st	2nd	3rd	4th	5th	6th
Number of patients.....	7	14	12	11	7	4
Number of samples.....	7	64	69	59	24	14
Acid reaction.....	5	25	26	41	16	10
Neutral reaction.....	0	9	13	10	6	4
Alkaline reaction.....	2	30	30	8	2	0

TABLE XXVIII

DETERMINATION OF URINE VOLUME, AMMONIA, AND TITRATABLE ACID AT VARYING INTERVALS IN SEVERELY WOUNDED SOLDIERS; 24-HOUR TOTAL VALUES TABULATED

	1st Day (14 Patients)			2nd Day (12 Patients)			3rd Day (10 Patients)			4th Day (5 Patients)			5th Day (2 Patients)		
	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.
Avg. value	1690	27.8	15.8	1614	43.0	22.1	1240	56.3	22.3	1400	53.3	21.8	1185	45.1	10.0
Highest value	6100	49.1	35.0	3460	82.8	43.7	2160	107.1	53.5	1885	88.0	34.7	1320	48.8	10.5
Lowest value	400	7.7	0	550	11.0	0	680	0	0	720	1.6	12.6	1055	41.4	9.6

TABLE XXIX

DETERMINATION OF URINE VOLUME, AMMONIA AND TITRATABLE ACID AT VARYING INTERVALS IN SEVERELY WOUNDED SOLDIERS, EACH GIVEN A TOTAL OF 40 GM.  $\text{NaHCO}_3$  INTRAVENOUSLY DURING 1ST AND 2ND DAYS; 24-HOUR TOTAL VALUES TABULATED—5 PATIENTS

	1st Day			2nd Day			3rd Day		
	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.	Vol. Cc.	$\text{NH}_4$ mEq.	Tit.Ac. mEq.
Average value.....	1845	17.3	7.0	1125	13.8	3.0	1090	35.2	13.5
Highest value.....	2745	39.1	23.5	1675	18.2	6.7	1425	57.4	35.3
Lowest value.....	1045	7.8	0	400	4.8	0	750	23.8	0.3

normal by the method used. Individual readings, however, were frequently below normal, the lowest being 4.5 Gm./100 cc. In only one instance, and in that more than 12 days after wounding, was the highest plasma protein concentration above the normal range. Much the same holds for hemoglobin, though the average values during the fourth to twelfth days were below the range of normal. In other words, during convalescence and despite parenteral therapy, mild hypoproteinemia and definite anemia were the rule.

In evaluating the state of wound shock in these patients, several criteria may be tested. The systolic blood pressure, pulse pressure and pulse rate are pertinent, as are plasma volume, concentration of plasma protein and hematocrit; the amount of plasma and blood given in resuscitation reflect to some extent the surgeon's estimate of the gravity of the patient's condition, and the death rate relates in some degree to the severity of shock, though the presence of other etiologic factors tends to obscure this point. In Table XI, these data, as provided by 86 cases, are tabulated and grouped according to the systolic blood pressure readings before treatment. In Table XII, the data are analyzed with plasma volume as the critical factor, while in Table XIII the hematocrit readings are the basis for analysis. From these tabulations, it would appear that systolic blood pressure in untreated wound shock affords the basis of analysis yielding the best agreement between the different factors under consideration.

There are various circumstances which might be expected to raise the nonprotein nitrogen of the blood following grave wounding. Among these are dehydration, sepsis and fever and increased metabolic breakdown, shock and hypotension with decreased renal blood flow, hemorrhage into the gastrointestinal tract, renal damage from sulfonamide therapy and hemoglobinuric nephropathy. As shown in Table XIV, azotemia is often present during the first ten days of convalescence. In some cases this occurs during the first day after wounding, but elevation of nonprotein nitrogen is more pronounced and more common at the end of the first week. In most cases the azotemia is not severe. In Table XXI appear data from a case of severe renal dysfunction which progressed to anuria, with subsequent recovery. Azotemia, hypertension, albuminuria and cylindruria were present and the specific gravity of the urine was low. The patient's condition improved greatly after urine volume became normal, but the subsequent state of his renal function could not be determined owing to his evacuation. Coincident with nitrogen retention in this case, there was sharp elevation of blood sulfonamide content. It is impossible to say what the cause of the renal insufficiency in this case was, but probably it resulted from a combination of unfavorable circumstances. The wounds were extensive and included direct trauma to one kidney, the blood pressure was at zero values on admission to hospital, blood volume was seriously reduced, a large amount (25 Gm.) of sulfonamide was administered in the first 24 hours, and two liters of blood were given before and during operation. From the present study, it is not possible to say how frequently serious renal damage occurs



in the gravely wounded, but in this group of 114 cases there were at least four of them showing some degree of renal impairment.

In the management of these cases, sulfonamide was employed variously, and with uncertain enthusiasm. Theoretically, each wounded soldier received 5 Gm. of crystalline sulfonamide topically and 6 Gm. orally as part of routine forward medical care. At the time of definitive surgical operation from 5 to 10 Gm. of sulfanilamide was applied to wounds of pleural or peritoneal cavity; postoperatively from 2.5 to 5.0 Gm. sodium sulfadiazine was given as a daily intravenous injection for five to seven days, particularly in cases of penetrating abdominal wounds. Actually, this routine was frequently modified in any or all of its parts, and precise knowledge of how much sulfonamide had been used in the course of first-aid and definitive surgical care was never available. The total dosage was a matter of guesswork. For such reasons the data shown in Table XV are of special interest. All of the 89 patients whose blood was examined at various intervals after admission to hospital, supposedly were under sulfonamide therapy. The values for blood concentration indicate that many received little or none of the drug, and the variability of the blood values showed that only dubious and uncertain benefit could be expected.

In several instances the authors were given a chance to note the rapid changes in the blood picture resulting from fulminating clostridial myositis. As edema of the involved and adjacent tissues rapidly develops, plasma protein concentration falls and plasma volume declines, while red cell hematocrit may remain normal, or even rise. The pattern of the blood, thus, may come to resemble that in severe burns. Plasma infusions are clearly an important part of treatment. In Tables XXIII and XXIV, illustrative data are tabulated as provided by two patients with clostridial myositis, clinically diagnosed as due to *C. oedematiens*.

There is considerable evidence at hand showing that the convalescent period immediately after severe wounding is marked by frequent disturbances in fluid balance. Dehydration in varying degree is often present, despite the fact that infusions of 5 per cent glucose solution and physiologic salt solution were part of postoperative care. An examination of the data in Tables XVI to XXIV, inclusive, discloses the frequency with which fluctuations in plasma protein concentration and red cell hematocrit occur. The specific gravity of the urine, as shown in Table XXVI, varied widely but in the main a concentrated urine was excreted during the first four days after wounding. The average specific gravity of the urine in the cases studied was 1.020. The prevalence of dehydration is further indicated by the figures for average daily urine volume and for minimal urine volume during the various days observed, and by the frequency of azotemia and hypochloremia as shown in Tables XVI to XXIV. Since 48 per cent of the group of ground force casualties studied had received penetrating abdominal wounds, disturbances in fluid balance would be expected and in fact did form a challenging problem in surgical after-care.

Included in the plan of study was investigation of the importance of acidosis as a part of the picture of wound shock. Owing to the limitation on available biochemical methods, the question was approached indirectly through analysis of the urine. In a group of 14 patients it was possible to make quantitative collections of urine beginning with the first specimen passed following admission to hospital a few hours after wounding, and to examine individual samples for ammonia content and titratable acid. In addition, a few patients (five) were given 40 Gm. of sodium bicarbonate intravenously during the course of the same studies. From the data given in Table XXVII, one sees that ammonia and titratable acid were present in the urine in quantities sufficient to effect considerable saving of fixed base.<sup>8</sup> The ratio between ammonia and titratable acid is in the normal range, and it is a fair inference that these phases of renal function suffered no serious impairment. The findings are consistent with a presumption that some degree of base-deficiency was the rule in the cases observed. The administration of sodium bicarbonate on the first two days after wounding resulted in a reduction in the amount of ammonia and titratable acid excreted, and adds to the validity of the above concepts.

#### SUMMARY

Clinical and biochemical investigations were made on 100 ground force casualties and 14 air combat casualties; all were selected cases with severe wounds inflicted by high explosive missiles. The study began immediately after admission to a forward hospital a few hours after wounding and continued for one to two weeks. Data were obtained of significance in the analysis of wound shock, resuscitation, and postoperative care.

#### CONCLUSIONS

1. The syndrome of traumatic shock due to wounding by high explosive missiles was notable for its variability.
2. Reduction in blood volume was a characteristic finding.
3. Hemoconcentration as evidenced by elevation of red cell hematocrit or plasma protein above normal ranges, was not encountered in the absence of burns or complicating clostridial myositis.
4. Despite restorative therapy, anemia and hypoproteinemia were the rule during convalescence.
5. Quantitative improvements in blood volume and in concentration of plasma protein and hemoglobin did not occur in response to replacement of plasma and blood.
6. No evidence of overdosage in plasma and whole blood therapy was detected.
7. Dehydration and azotemia were common in early convalescence.
8. In fulminating clostridial myositis, with edema, plasma protein concentration and blood volume fell rapidly.
9. Erratic effects were obtained from sulfonamide therapy if the concentration of the drug in the blood is significant.

10. Base deficiency, when present, was of mild degree as evidenced by the urinary reactions.

11. The effectiveness of the surgical management of this selected group of the gravely wounded is attested by the low mortality rate during the period of observation.

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# EVACUATION HOSPITAL EXPERIENCES WITH WAR WOUNDS AND INJURIES OF THE CHEST

## A PRELIMINARY REPORT

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THE CASES which form the basis of this report were all seen in one Evacuation Hospital over a period extending from November 8, 1942, to August 2, 1944. During this time the hospital was at varying distances from the front lines in the North African and Italian campaigns. In most situations casualties were admitted 2 to 12 hours after injury. At Anzio, when the hospital was only a few miles from the front line and well within artillery range of the enemy, many casualties were received within a few minutes after being wounded. In all, 1,210 patients with wounds and injuries of the chest were treated, this number constituted 6.9 per cent of the total battle casualties and injuries admitted to this hospital. The experience gained in the management of these cases has led to the development of certain policies in regard to preoperative, operative and postoperative care of the patients who have suffered wounds of the chest. It is not our purpose to discuss in detail all the problems of the surgery of thoracic wounds. However, certain fundamental concepts may well be emphasized in this preliminary report. The various types of wounds of the chest will be discussed separately, giving some statistics and, in most instances, illustrating methods of management by case reports.

The rôle we play in a forward installation in respect to chest lesions is to: (1) Save lives. (2) Be conservative. (3) Evacuate patient to Base Hospital when transportable.

### GENERAL MANAGEMENT OF CHEST CASES

The patient is propped up to a semisitting position if he is not in profound shock or unconscious. All clothing is removed from the chest and abdomen to permit an adequate examination. Immediate attention is given to shock and hemorrhage by starting replacement therapy, preferably with whole blood. The normal relationship of the intrathoracic organs is promptly restored, inasmuch as disturbances here may be responsible for shock. This may be attained, first, by adequately covering open chest wounds, if they exist; and second, by aspiration of blood and air from the pleural cavity. Thoracentesis for blood can be done nicely by using a transfusion vacuum bottle (Fig. 1). Blood so withdrawn is used for autotransfusion; though if an abdominal injury is suspected, the blood is not to be given until thoracotomy has proven the absence of contamination with gastric or intestinal contents. If pressure pneumothorax exists, a trocar-thoracotomy is done, placing the catheter in the 2nd interspace anteriorly in midclavicular line. The catheter is connected to a water-seal bottle.

All chest wounds, or chest wall injuries, with pain, receive intercostal nerve block (4 to 6 cc. of 1 per cent novocaine) two segments above and below the lesion. Paravertebral sympathetic block is occasionally substituted when

the lesion is far posterior. If morphine has not been given previously,  $\frac{1}{6}$  gr. and atropine sulfate 1/100 gr. are given intravenously.

Excessive secretions and blood in the trachea and bronchi are aspirated by tracheal catheter suction. Occasionally bronchoscopic aspiration is necessary. Oxygen therapy is often useful in combating shock and anoxemia. The measures outlined above will render most patients with wounds of the chest good operative risks. Roentgenograms in two planes are always taken prior to operation. As soon as all indicated measures are carried out, necessary surgery is performed.

Anesthesia of choice in all suspected sucking wounds of the chest is gas-oxygen-ether, with intratracheal tube in position. This is necessary as all penetrating and perforating wounds of the chest are potentially sucking wounds and usually do suck when the débridement of the chest wall is complete. If the positive pressure anesthesia machine is not available, local anesthesia is then used. Open drop-ether and sodium pentothal anesthesia should never be used in the management of these wounds.

Débridement of all chest wall wounds must be thorough, which entails removing all devitalized tissue and loose rib fragments. Following débridement sucking wounds are closed by approximating muscle and fascia layers, thus, occluding the defect in the pleura. The skin is also closed when necessary to assure an air-tight closure. It should be emphasized that the pleura itself need not be sutured. Every effort is made to secure and maintain complete expansion of the lung, using positive pressure anesthesia and aspirating any residual air by needle. At the close of operation repeat the intercostal nerve block. Hemothoraces are aspirated without air replacement every 24 to 48 hours until the pleural cavity is free of fluid. Intratracheal catheter is used as indicated in the postoperative period.

#### PENETRATING AND PERFORATING WOUNDS OF THE CHEST

Penetrating and perforating wounds of the chest, with no indication for emergency thoracotomy, comprise the vast majority of the cases in this series. These cases, for the most part, require only simple débridement of the chest wall wound. The preoperative and postoperative care of these patients is most important.

These cases frequently have an accompanying hemopneumothorax, with associated severe pain (chest wall). Such factors may produce symptoms of shock and definitely aggravate shock when present. Thus, the problem of correcting this pathophysiologic condition should be undertaken immediately and vigorously by: (1) Aspiration of the hemopneumothorax (using blood for autotransfusion). (2) Doing an intercostal nerve block. This allows the patient to breathe deeply and cough painlessly so as to drain the bronchial tree of excessive bronchial secretion that seemingly accompanies chest wall and pulmonary trauma.

The following is an example of a perforating wound of the chest which was treated conservatively:

**Case 1.**—This patient suffered a perforating wound of the left chest from a 32-caliber bullet. He was admitted to the hospital shortly thereafter in moderate shock, and with some dyspnea. There was no hemoptysis and no gross bleeding. The wound of entrance was one centimeter in diameter at the level of the fourth rib anteriorly in the midclavicular line; the wound of exit was small and just beneath the inferior angle of the right scapula. The wounds were not sucking. No evidence of hemothorax or pneumothorax existed. An intercostal nerve block was done. Attempted aspiration of the chest yielded no blood or air. The patient was readily stabilized without replacement therapy. Under local anesthesia, the wounds were débrided, and no evidence of sucking found. The wound surfaces were powdered with sulfanilamide and vaselined gauze dressings were applied. On the first postoperative day 100 cc. of blood was aspirated from the left chest cavity. On the fifth postoperative day the patient was sitting up, breathing comfortably and had no complaints. He was evacuated to the rear on the sixth postoperative day.

**COMMENT:** In this case the relief of pain by intercostal nerve block brought an apparently ill patient into a comfortable state. While it is true that blood and fluid do not always produce marked symptoms, time and experience has demonstrated that patients are able to return to duty sooner when the pleural cavity is kept dry and the lung is allowed to reexpand.

#### SUCKING WOUNDS OF THE CHEST

Large sucking wounds of the chest demand prompt attention and may present some difficulty in closure. When a wound is large and the chest open, fluid and clots should be aspirated through the wound; furthermore, one should endeavor to be certain that hemorrhage has stopped and that there has been no injury to the diaphragm. Intrapleural foreign bodies and only readily accessible fragments in the lung should be removed; occasionally it is necessary and expedient to enlarge the wound to do this, as exemplified in the following cases:

**Case 2.**—This patient had a perforating gunshot wound of the left chest, with wound of entrance anterior in the region of the third rib and the wound of exit through the scapula just above the angle. An hemopneumothorax existed and there was also a perforating wound of the left hand. Six hours after being wounded an intercostal nerve block was done, and 400 cc. of blood was aspirated from the left pleural cavity; this blood was autotransfused. (Prior to the nerve block and aspiration atropine sulfate gr. 1/100 and morphine sulfate gr. 1/4 were administered). The blood pressure was 108/70. Ten hours following the wound, operation was performed under endotracheal positive pressure anesthesia. The chest wound was found to be gaping and air and blood were spluttering therefrom. A perforation of the lung lay directly beneath the chest wall perforation and the air was seen to be coming from this wound in the lung. The chest wall wound was enlarged and the three-inch laceration of the lung, containing a bronchial fistula, was closed with interrupted silk sutures. Closure of the chest wall wound was done in anatomic layers with catgut, and the skin was closed with silk sutures. A small catheter was placed in the third interspace in the midclavicular line. The posterior wound was then débrided and also the wound of the right hand. At the end of the procedure the blood pressure was 104/78. The patient was given penicillin 25,000 units intramuscularly every three hours. On the second postoperative day good breath sounds were heard throughout the posterior chest. The anterior catheter which had been connected with a water-seal bottle immediately postoperatively had ceased to drain four days postoperatively; it was removed at that time. On the fifth postoperative

day the patient had a temperature of 103° F., and signs of fluid posteriorly, 1,000 cc. of thin bloody fluid was aspirated from the left chest. The patient was evacuated in good condition, with the note that further thoracentesis might be necessary.

COMMENT: Too much dependence was placed on the anterior catheter to drain the chest cavity. The patient's position had been changed to effect fluid drainage, but without success. If daily thoracentesis had been done he should have been relatively dry at the time of evacuation.

Case 3.—This soldier was wounded by a machine gun bullet, and was admitted to the hospital in severe shock, with a blood pressure of 40/0 and shallow respirations (30 per minute). The wound of entrance was in the left chest at the lateral border of the left scapula at the level of the fourth rib. The foreign body could be palpated in an hematoma the size of a golf ball in the right chest wall in the posterior axillary line at the level of the fourth rib. Three and one-half hours after being wounded (0800 hours) an intercostal nerve block was done. At 1245 hours atropine sulfate gr. 1/100 was administered intravenously and 1,300 cc. of blood was aspirated from the left pleural cavity and given as autotransfusion in addition to 600 cc. of whole blood and 250 cc. of plasma. The blood pressure then became stable at 100/60. The patient vomited and coughed up a blood-tinged milk-like substance. The presence of chyle from a thoracic duct wound or sulfathiazole from an esophageal wound was considered. The patient was given a small amount of barium for roentgenologic examination, but no lesion in the esophagus could be demonstrated.

At 1330 hours of the same day, under oxygen-ether intratracheal anesthesia, the wound was débrided. It was found to extend through the scapula and it was necessary to reflect the scapula through a regular thoracoplasty incision to complete the débridement. The lower border of the fourth rib and the fourth intercostal bundle were found to be destroyed and a sucking wound 4 cm. in length was found. Two hundred cubic centimeters of blood were aspirated from the left pleural cavity. The patient's condition did not warrant further exploration of the chest cavity. The sucking wound was closed by approximation of muscle and fascia over it. The machine gun bullet was then removed from the right chest wall. Six hundred cubic centimeters of additional blood was given during operation. The patient was returned to ward in good condition. Twenty-five thousand units of penicillin was administered intramuscularly every three hours. He was evacuated to the rear on the third postoperative day, with a dry chest.

Case 4.—This patient was wounded by artillery fire. Dyspnea, weakness and pain in the abdomen developed immediately. He was admitted to the hospital one hour and forty-five minutes after being wounded, and was in fairly good condition. The abdomen was spastic, but there was no rebound tenderness. There was a penetrating wound 2 cm. in diameter in the left posterior scapular line at the level of the ninth interspace. There were two small perforating wounds in the left arm. There were signs of a large hemothorax, but no blood could be obtained by aspiration. The intercostal nerves in the region of the wound were blocked. Then, under oxygen-ether anesthesia, with intratracheal tube in place, the wound of the left posterior chest wall was excised. There was much destruction of the muscle and the tenth rib. With débridement of the wound a large clotted hemothorax was revealed. Approximately 1,800 cc. of clotted blood were evacuated from the left pleural cavity. A puncture-like laceration was found in the lingula of the left upper lobe. This laceration was 5 cm. in diameter, and was bleeding freely and bubbling air. The lacerated lung was repaired with interrupted silk sutures. The diaphragm was not involved. A catheter was placed in the eighth interspace in the posterior axillary line. Sixty thousand units of penicillin was introduced intrapleurally. The incision was closed in anatomic layers with catgut sutures. Six hundred cubic centimeters of blood and 250 cc. of plasma were given during operation. The patient returned to ward in good condition. Penicillin therapy was

continued by the intramuscular route, and the catheter was removed 48 hours post-operatively. There were some signs of fluid at the base, but only 20 cc. of thin fluid could be aspirated. Breath sounds were present anteriorly and posteriorly. The patient was evacuated to the Base on the sixth postoperative day.

COMMENT: The size of the wound after adequate débridement of the chest-wall permitted evacuation of a large clotted hemothorax, repair of a laceration of the lung and a bronchial fistula, and inspection of the diaphragm.

The above cases represent most of the common problems encountered in the sucking chest wound and illustrate the usual method of handling them. When there is extensive destruction of muscle and ribs, proper débridement of the wounds ordinarily opens the pleural cavity; then an estimation of the intrathoracic damage is made. Frequently, any necessary repair can be effected by enlarging the wound slightly.

#### THORACOTOMY INDICATIONS AND APPROACH

There are not many indications for formal emergency thoracotomies in Forward Hospitals. In fact, we believe there are only four, namely: (1) Cases with continued gross bleeding. (2) Uncontrolled bronchopleural fistulae (such as lacerated bronchi). (3) Suspected and known thoraco-abdominal lesions (which will be discussed separately). (4) Suspected and known esophageal wounds.

Under sucking wounds certain indications were mentioned for enlarging those wounds and such enlargements are properly thoracotomies, but we ordinarily think of them as extensive débridements; of these and formal thoracotomies there were 110 cases (which constituted 10 per cent of the group), not including the thoracoceliotomies.

The elective removal of foreign bodies and decortication of organized hemothorax are not performed routinely in an Evacuation Hospital, but in situations where Base Hospitals have been far removed, it has been expedient to retain these patients for definitive surgery.

When thoracotomies are indicated, in some instances they may be done through the wound of the chest wall, provided the lesion is in the site of the elective incision (*i.e.*, posterolateral area). This requires enlargement of the débrided wound. Against this procedure is the fact that these wounds frequently break down from infection. For this reason, when a large thoracotomy incision must be made, it should, whenever possible, be kept away from the original wound. Indications for thoracotomy will be demonstrated by illustrative cases.

#### HEMORRHAGE FROM LARGE INTRATHORACIC BLOOD VESSEL

When there is evidence of bleeding from a large intrathoracic blood vessel (this largely determined by route taken by missile—usually through the neck and supraclavicular region—and by the fact the hemothorax is clotted), the case should be explored as soon as the blood pressure becomes stabilized. Procrastination in such cases, in our experience, has been disastrous, as illustrated in the following two cases:



**Case 5.**—This patient was wounded by shell fragments. He received a penetrating wound of the left chest with the entrance wound in the left neck, and also penetrating wounds of the right upper arm and the left hip. He was admitted to the hospital with a large hemothorax five hours after having been wounded. After several unsuccessful attempts to aspirate this hemothorax it was decided the blood was clotted. The wound of the neck was débrided, and the tract partially explored where it ran superior to the first rib. The wound was powdered with sulfanilamide and covered with a vaselined gauze dressing. The first three days postoperatively no aspiration of the chest was attempted; 400 to 500 cc. of blood were aspirated daily from the left chest for the next five days. The patient was supported by numerous blood transfusions. On the eleventh postoperative day 900 cc. of thin bloody fluid were aspirated. On the twelfth postoperative day the patient suddenly went into severe shock; the radial pulse was imperceptible and no blood pressure reading could be obtained. Respiration was slightly labored, and the skin was cold and clammy. The breath sounds on the left were distant. The patient was given 1,000 cc. of blood, and he rallied satisfactorily. Attempted aspiration was unsuccessful. The following day his pulse was 148. Four hundred cubic centimeters of blood-tinged fluid was aspirated. Under oxygen-ether-intratracheal anesthesia a sickle-shaped incision was made from the middle third of the clavicle to the fifth costosternal junction. The first rib was excised at the sternocartilaginous junction. As the pleural cavity was entered copious quantities of blood poured out. Rapidly, the second, third and fourth ribs were severed at the sternocartilaginous junction. A finger was used to compress a rent in a bleeding vessel at the apex of the chest. The bleeding was from the region of the subclavian artery and innominate vein. Apparently, local infection had completed the laceration of these vessels. The bleeding was controlled eventually by gross clamping and mass sutures at the apex of the chest. The chest wall closure was effected with catgut sutures for muscle and fascia and silk sutures for the skin. A catheter was placed in the eighth intercostal space. The patient's blood pressure was imperceptible through much of the operation, although intravenous blood was started prior to operation in both ankles and the right arm; 3,000 cc. of blood were given during operation and 750 cc. immediately following operation. One hour postoperatively the blood pressure was 100/60, and four hours postoperatively it was 102/80. Oxygen was discontinued one hour after the operation.

The postoperative course was uneventful the first 13 days. When the hospital blew down in a snow storm this patient, with 700 others, was evacuated to another hospital. The catheter was not draining at this time. He was transferred to a General Hospital four days later. On admission there the following note was made: "Dyspneic, distressed, with intercostal catheter not draining." On the twenty-first postoperative day a large tube was inserted in the eighth rib bed; the pus which drained was putrid. There was no bronchial fistula and the anterior wound was nicely healed. Steady improvement followed this procedure."

**COMMENT:** The direction taken by the missile and the early clotting of blood indicated the possibility of a large vessel laceration. However, in the absence of shock and other evidence of gross bleeding, thoracotomy seemed contraindicated at the time. Subsequent events suggest that it would have been the better procedure. Intravenous fluids started in three veins before surgery unquestionably saved this patient's life.

**Case 6.**—This patient was admitted to the hospital two hours after sustaining shell fragment wounds; one of which was a 3- x 2-cm. penetrating wound in midline of the neck above the thyroid cartilage and the other a 1- x 2-cm. penetrating wound in the right lateral portion of the neck in the same plane. On admission, he was not in shock or experiencing any respiratory distress. Attempted aspiration was unproductive. Five hours after having been wounded, under intratracheal oxygen-ether anesthesia, a thy-

roidectomy-type incision was made and the right sternocleidomastoid muscle divided. Diffuse bleeding, which was thought to be coming from the right innominate vein, was in evidence beneath the right clavicle. Bleeding was controlled by a gauze pack, which was left in place. At completion of this débridement blood pressure was 92/68. Eighty cubic centimeters of blood was aspirated from the right chest; however, more blood remained, which was clotted and unspirable. One hour postoperatively the patient went into profound shock and he expired ten minutes later.

Autopsy revealed intrathoracic laceration of the right subclavian artery and innominate vein; the right thoracic cavity was filled with clotted blood. Massive hemorrhage was the immediate cause of death.

COMMENT: This patient should have had a formal thoracotomy, and an attempt made to ligate the lacerated vessels. In cases such as these, it is advisable to start blood and plasma in every available arm and leg prior to operation.

#### LACERATED BRONCHI WITH BRONCHOPLEURAL FISTULA

Any case with pressure pneumothorax which cannot be controlled by needle aspiration or by a large catheter in the anterior chest should have an immediate thoracotomy.

We think it is noteworthy to report these two cases of lacerations of main stem bronchi, with large defects, because it is only in rare instances that such patients live to be evacuated from the battle field. At the Anzio Beachhead, hospitals occupied a peculiar position, in that they were part of the battle field, and patients were injured on or adjoining the hospital area. These are the only cases of main-stem bronchi defects, to our knowledge, to reach a hospital alive. Most certainly, such cases deserve emergency thoracotomies.

Case 7.—The patient was received at this hospital one hour after sustaining a shell fragment wound of the right chest, eighth interspace, posteriorly. Presumably, he was in a prone position when wounded. He immediately became aware of a sucking wound of the chest and inability to move his lower extremities. Dyspnea followed. On admission, he was in shock and suffering profound respiratory embarrassment. Complete paralysis below the eighth dorsal segment existed. A large 5- to 6-cm. diameter wound in the eighth interspace posteriorly was sucking air, draining blood and was filled with clothes and bone fragments. The sucking was stopped with a vaselined gauze pack to the wound. A paravertebral nerve block of the sixth to tenth intercostal nerves improved the respirations and the patient began to cough up a large amount of blood. Twenty-five grams of serum albumin elevated the blood pressure to 96/52, and the chest was immediately aspirated of 800 cc. of blood, which was given as an auto-transfusion. Insertion of an intercostal tube relieved the developing pressure hemothorax. The patient became fairly well stabilized nine hours after injury, when suddenly pneumothorax increased, and operation then became an emergency. Under intratracheal oxygen-ether anesthesia the wound in the region of the eighth rib was excised and a posterolateral thoracotomy incision in the right eighth interspace was made. A large ragged bullet-shaped shell fragment, 12 cm. in length, was found penetrating a main-stem bronchus from which air and blood was flowing freely. The azygos vein was found to be lacerated and was sutured, but not completely occluded. There was an irregular 2.5-cm. defect in the posterolateral wall of the right main-stem bronchus just distal to the bifurcation of the trachea. This defect was approximated, after considerable difficulty, with interrupted silk sutures and reinforced with muscle. The repair was water-tested and no leakage experienced. A 12- to 14-cm. long transverse laceration of

the upper lobe was closed with interrupted silk sutures. The lung was then reexpanded, except for a portion of the upper lobe in the region of the lacerated area. The closure of the incision was done in anatomic layers with catgut sutures for deep layers and silk sutures for skin. The patient was in fair condition at termination of the operation. He had received 1,000 cc. of blood and 250 cc. of plasma during the procedure.

The patient underwent a stormy postoperative course, with abdominal distention and the accompanying sequelae of a cord transection. Seven days postoperatively a suprapubic cystostomy was performed and a hip spica applied to insure the patient's

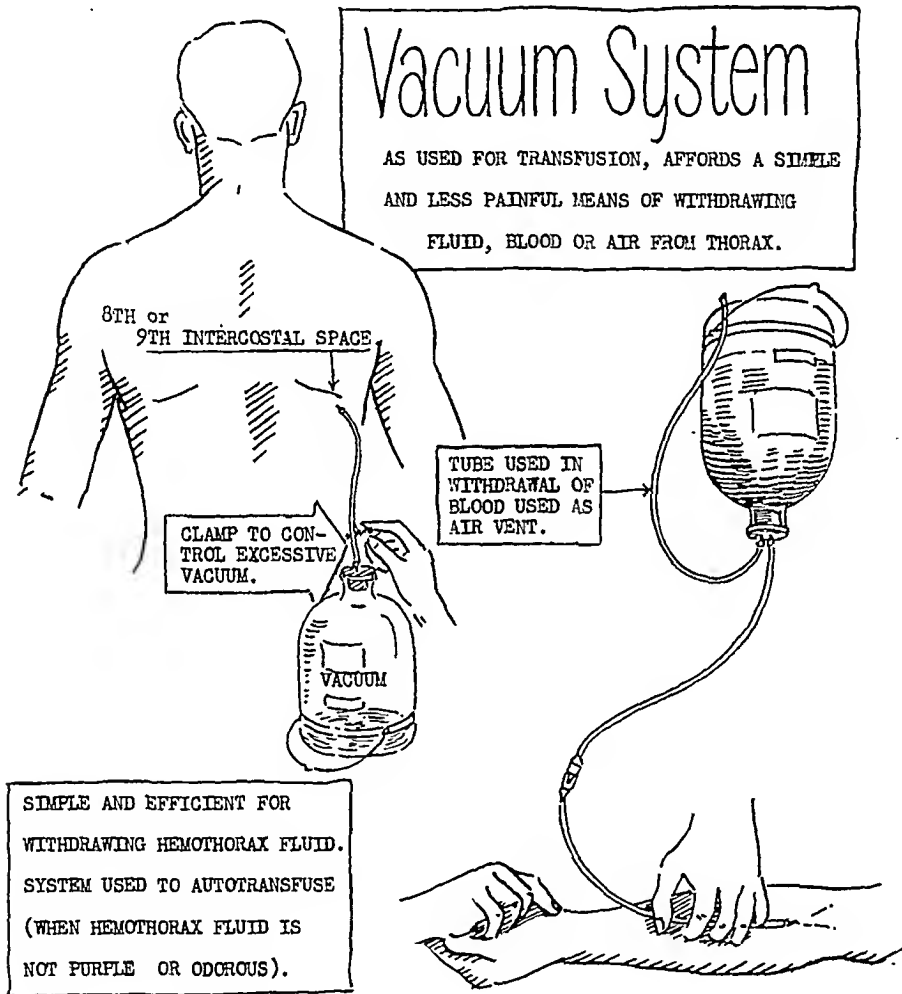


FIG. 1

comfort and to facilitate his handling in evacuation to the rear. Although the right lung remained expanded, on the twelfth postoperative day an infection of the incision developed at the site which included the original wound (experiences such as this illustrate the inadvisability of including the wounded area in the thoracotomy incision). An empyema ensued. Four days later he was sufficiently stabilized for evacuation to the rear. It should be noted that he had received 25,000 units of penicillin intramuscularly every three hours for ten days postoperatively. No sulfonamides were given (when penicillin is available, sulfonamides are never used). Reports a month later stated there was an empyema cavity of 200 to 300 cc. remaining, and there was some return of sensation in the extremities. A progress note four months later recorded progress as "excellent."

**Case 8.**—This soldier was admitted to a hospital one hour and 30 minutes after receiving multiple penetrating shell fragment wounds, most notable of which was a large sucking wound of the seventh interspace posteriorly that involved the seventh Dorsal vertebra. Complete paralysis existed from the eighth dorsal segment downwards. Being in moderate shock, he was sustained with serum albumin and transfusion until his blood pressure became stable. He was received at this hospital in a dyspneic state, with intercostal catheter working and with air and blood in the right thorax. His chest was very "wet" and copious quantities of bloody exudate were aspirated. Then, under intratracheal oxygen-ether anesthesia, two hours after admission here, the right pleural space was opened at a selected site in the fifth intercostal space; 700 cc. of blood were evacuated from the pleural cavity. Air was seen bubbling from the right main-stem bronchus. There was a 2-cm. defect in the anterior and left lateral wall where a piece of the bronchus had been torn out approximately 1.5 cm. from the bifurcation of the trachea. With considerable difficulty, three heavy silk sutures were placed to occlude the defect (water-tested) and a muscle graft was sutured over the area. There was profuse bleeding in the wound exit in the seventh intercostal space at the level of the transverse process. This wound extended to the spinal canal and the cord could be visualized, but no damage was apparent. Bleeding was controlled only by a pack which was brought out through the wound. The pleura was then closed and the ribs approximated. Sixty thousand units of penicillin were deposited intrathoracically. Two catheters were inserted; one in the eighth interspace posteriorly, the other in the second interspace in the midclavicular line anteriorly. The patient had received 1,200 cc. of blood and 1,000 cc. of glucose during operation. Penicillin therapy, 25,000 units intramuscularly every three hours, was instituted. Forty-eight hours postoperatively the patient became irrational, had a temperature elevation to 104° F., and developed a stiff neck with other signs and symptoms of meningitis. Seventy-two hours postoperatively the temperature remained elevated to 103° F., stiffness of neck persisted and the general condition became more critical. At this time the hospital was forced to move forward; the patient was left at a Holding Hospital, and placed on the "seriously ill" list. His lung remained completely aerated. The patient had been receiving 25,000 units of penicillin intramuscularly every three hours throughout his hospital stay.

#### POSTOPERATIVE CARE

After operation, intercostal nerve block should be repeated and residual air aspirated by suction bottle in the 2nd intercostal space in the mid-clavicular line. All thoracotomies are drained with a catheter in the 7th or 8th intercostal space in the posterior axillary line. Postoperatively, all patients are aspirated with a long catheter which is inserted through the endotracheal tube or are aspirated by means of a bronchoscope. It goes without saying that bronchoscopic aspiration is more complete although it entails prolonged anesthesia and consumes more time, which is a real factor when there is a large back-log of untreated wounded. In our experience the long catheter aspiration has proven satisfactory.

#### THORACO-ABDOMINAL WOUNDS

There were 103 cases with coexisting wounds of the chest and the abdominal cavity (two died prior to operation). In six of these cases the wounds were caused by two or more missiles without injury to the diaphragm. The injuries below the diaphragm were limited largely to the upper abdominal viscera. In the treatment of these cases attention was focused primarily on

the chest; measures to relieve respiratory difficulties were instituted promptly. These consisted chiefly of insuring that the dressing adequately occluded the chest wound, aspirating the hemopneumothoraces, autotransfusion, and novocaine block of intercostal nerves in areas of the chest wounds. Relief of respiratory difficulty and treatment of shock were carried on simultaneously. With improvement in the patient's general condition an appraisal of the chest and abdominal injuries was made. The choice of approach to abdominal injury was determined largely by the fancy or experience of the surgeon. From our experiences with this group of cases, after studying in detail their postoperative course and reviewing the mortality figures, the claims of those who strongly advocate one approach over the other cannot be dogmatically substantiated, though for those familiar with the chest, the thoracic approach is definitely preferable. Forty thoraco-abdominal wounds were treated by thoracoceliotomy (all work done through chest incision), with ten deaths (25 per cent). Fifty-four thoraco-abdominal wounds were treated primarily through the celiotomy incision, with 17 deaths (31 per cent). Six thoraco-abdominal wounds were treated through a combined approach, with two deaths (33 per cent). Major Pat R. Ines, in preparing a report on the abdominal wounds treated in this hospital, has noted the high mortality that accompanies multiple abdominal visceral wounds. His figures indicate that mortality is in direct proportion to the number of viscera involved. The superior statistics for the thoracic approach are seen to be more apparent than real when the following table is studied:

	Wound of:								
	Abdomen Negative			One Abdominal Viscus			Two or More Abdominal Viscera		
	Cases	Deaths	%	Cases	Deaths	%	Cases	Deaths	%
Celiotomy.....	4	0	0	26	3	11	24	14	58
Left thoracoceliotomy.....	4	0	0	15	4	27	8	4	50
Right thoracoceliotomy...	0	0	0	10	0	0	3	2	66
Total.....	8	0	0	51	7	14	35	20	57

One flank wound lacerated the diaphragm. Nephrectomy and repair of the diaphragm were accomplished through a kidney incision.

These mortality figures indicate a somewhat higher death rate than those from abdominal wounds without involvement of the chest. But on comparison with similar upper abdominal visceral injuries there is no remarkable difference. However, the fact remains that the chest wound must first be converted into a nonsucking wound and the physiology of the chest stabilized prior to a thoracoceliotomy or abdominalceliotomy.

#### A—THORACIC APPROACH, LEFT-SIDED

No. of Cases: 27

Deaths: 8

Thoracic approach on a left-sided lesion is quite adequate unless the missile is directed from below the umbilicus upwards; a rare condition.

Case 9.—This soldier was admitted to the hospital with a severe perforating gunshot wound of the chest, with lacerations of the diaphragm, spleen, left lower lobe of lung and herniation into the chest of the stomach, spleen, colon and small bowel. Three hours after being wounded, under endotracheal ether anesthesia, a left-sided thoracotomy was performed with resection of eight inches of the ninth rib. The chest cavity was found to contain the entire stomach, tremendously dilated, the omentum and transverse colon with splenic flexure and a portion of the jejunum. The badly lacerated spleen was removed, and a stomach tube reduced the stomach 60 per cent in size. The left gastro-epiploic artery which was torn near its termination was ligated. The kidney, colon, stomach and bowel were found to be intact. The torn lesser omentum was repaired, and the diaphragm was closed in two layers with silk sutures. The tip of the lower lobe of the left lung, which was badly torn and bleeding, was resected and sutured with swaged catgut. A catheter was inserted intercostally, and closure was effected with paracostal sutures and suture of the muscle layers. Twelve days post-operatively the patient was evacuated to a Base Hospital.

COMMENT: This case rather typifies left thoraco-abdominal lesions, and illustrates the proximity of all left upper quadrant organs to the chest cavity and their accessibility through this approach. When the diaphragm is opened these organs actually ooze into the chest cavity.

Case 10.—In this instance a soldier received a shell fragment wound which penetrated the tenth interspace in the posterior axillary line. At a Forward Field Hospital exploration of the wound was done and a perforation of the diaphragm sutured. The wound was then hurriedly closed, apparently because the hospital was under shell fire. On admission to this hospital, 24 hours after being wounded, the patient was suffering severe abdominal pain, with distention. Accompanying the patient was a note by the surgeon stating that "he thought a celiotomy should be performed." Through a left rectus incision the abdomen was opened, and the peritoneal cavity found to contain clean blood although all viscera appeared intact. Thirty-six hours after operation the thoracotomy wound became edematous; crepitation and a foul odor were present. Upon exploration of the wound, the superficial muscle was found to be necrotic and characteristic gas gangrene was seen to exist. The patient expired 48 hours postoperatively. Findings at the autopsy revealed gas gangrene of the chest wall, and a perforation of the splenic flexure of the colon.

COMMENT: This case represents an injury to the retroperitoneal portion of the splenic flexure that was not identified through a celiotomy. This could have been handled simply, and easily, through a thoracotomy approach. That the lesion was not recognized is not the fault of the thoracic approach.

B—THORACIC APPROACH, RIGHT-SIDED

No. of Cases: 13

Deaths: 2

Thoracic approach for a right-sided thoraco-abdominal lesion is usually the procedure of choice.

Case 11.—After having sustained a penetrating wound of the right lower chest region the patient was admitted to the hospital shortly thereafter, with a rigid abdomen. The tenth right rib was resected and a laceration of the lower lobe of the lung sutured. The diaphragm was found to be perforated and the foreign body to lie in a tear in the liver. Inspection of the hepatic flexure, duodenum and kidney disclosed no injury, nor were other intra-abdominal viscera injured. The liver was drained subdiaphragmatically and the diaphragm closed in two layers with interrupted silk sutures. The patient was evacuated to the rear six days later in good condition.

COMMENT: In the 17 cases where right thoraco-abdominal lesions existed it was necessary to make an additional abdominal incision in only five instances.

## C—ABDOMINAL APPROACH

*No. of Cases: 54**Deaths: 17*

Case 12.—This patient was admitted to the hospital, with a blood pressure of 90/50 and pulse of 140, after having experienced a gunshot wound of the left chest and abdomen. Prior to admission here he had received 500 cc. of plasma. Upon arrival at this installation no respiratory difficulty was apparent and breath sounds were present, though diminished on the left. The abdomen appeared somewhat spastic and moderately tender. The patient complained of suprapubic pain. A perforating wound of the left chest existed with a wound of entry 1.5 cm. in diameter, in the seventh interspace anteriorly, two inches from the midline, and a ragged wound of exit, 7.5 cm. in diameter, in the ninth interspace, just medial to the posterior axillary line. Twenty-five to 30 cc. of blood and a small amount of air were aspirated from the left pleural cavity; 500 cc. of plasma administered and a blood transfusion was begun prior to operation. Then, under ether-oxygen anesthesia, a subcostal incision was made. The peritoneal cavity was found to contain approximately 800 cc. of blood, which was mixed with gastric contents. Exploration disclosed lacerations of the spleen, diaphragm and stomach, which was distended. Entry and exit wounds in the cardia of the stomach were closed and inverted in two layers with chromic catgut. The lesser peritoneal cavity was not involved. The spleen was then delivered and a 6-cm. sucking laceration of the posterior portion of the diaphragm presented itself. The spleen was removed. A large laceration of the diaphragm was closed with difficulty, while another nonsucking laceration of the anterior diaphragm was easily repaired. The closure of the abdomen was done in layers. The patient's condition was not satisfactory during the entire operative procedure, and he expired on the operating table while the skin sutures were being placed. The operation lasted 90 minutes, the greater part of which was consumed in effecting closure of the diaphragm. At no time did the patient's blood pressure exceed 90/60, and in spite of constant administration of blood there was a gradual fall in the blood pressure during the last 30 minutes of the procedure.

COMMENT: All patients with suspected perforations of the diaphragm should have an intratracheal tube in place. The sudden collapse of the left lung in an already shocked patient was directly conducive to the above fatality. The large sucking diaphragmatic perforation was not apparent until the lacerated spleen was delivered for removal. Upon the delivery of the spleen the tamponade of this organ to the perforation of the diaphragm was thus destroyed, and immediately a large sucking wound presented itself in an inaccessible position. The diaphragmatic laceration had to be more or less ignored, except for an ineffective gauze pack, until after the spleen was removed. Two things are apparent: This patient should have had an intratracheal tube, with facilities for maintaining positive intrapulmonic pressure present during operation. This case could have been handled very easily through a thoracic approach.

Case 13.—This soldier was admitted to the hospital nine hours after being wounded by shell fire. Examination disclosed a 1-cm. penetrating wound of the chest in the eighth interspace in the anterior axillary line, with a fragment lying posteriorly at the level of the first lumbar vertebra; also, a perforating wound of the left thigh, a penetrating wound of the right thigh, and a penetrating wound of the left testicle. On

arrival here the patient's blood pressure was 92/30. One thousand cubic centimeters of blood and atropine sulfate gr. 1/100 were administered intravenously. Chest aspiration produced 150 cc. of blood, but no air. (As chest pain was not a factor in this case, a nerve block was not indicated.) Nine hours after the wound was incurred, under intra-tracheal oxygen-ether anesthesia, the wounds of the chest were débrided and closed; a left subcostal incision was made; and the lacerated and bleeding spleen was removed. The kidney was also found to be torn. (Microscopic examination of the urine showed 8 to 12 red blood cells per high powered field.) A drain was inserted through the flank retroperitoneally. Examination of the stomach, colon and small intestine disclosed no injury. The perforation in the anterior portion of the diaphragm was repaired with catgut sutures and the abdominal incision closed with catgut and silk retention sutures. The wound of the left testicle was débrided and the left testicle removed. The perforating wound had entered the right compartment of the scrotum, but the right testicle was only slightly injured. A rubber drain was inserted through the lower portion of the scrotum. The wounds of the thighs were débrided and foreign bodies removed. Immediately following operation 1,000 cc. of air were aspirated from the left chest cavity. The patient had received 1,000 cc. of blood during operation. Postoperatively, he was placed on penicillin therapy, 25,000 units intramuscularly every three hours. On the second postoperative day an aspiration of the chest cavity yielded 200 cc. of bloody fluid. On the eleventh postoperative day the patient was evacuated to the rear in good condition.

COMMENT: This case was properly managed, as the chest wound was closed prior to celiotomy and the chest aspirated. These abdominal injuries could have been managed easily through a thoracic incision.

#### CHEST WALL WOUNDS

Chest wall wounds without intrapleural penetration and without contusion of the lung are handled as any other minor wounds. They do not constitute a large group of cases. The wound tract is excised, foreign bodies removed and the wound left open. One should not overlook intrathoracic disturbance merely because the superficial wound appears benign. There are some chest wall wounds without pleural penetration in which there is a varying degree of contusion or local blast injury to the underlying lung. These wounds may be quite serious and demand the same attention and care as intrathoracic wounds.

Case 14.—This patient stated that he was picked up by Aid men one to two hours after being struck by shell fragments in the right shoulder and the left knee. He arrived at the hospital 11 hours after sustaining his wounds, with a moderate hemothorax and "wet" lungs apparent. Many loud râles and rhonchi were heard. There existed a perforating wound of the right upper chest. Roentgenologic examination disclosed comminuted fractures of the posterior portion of the second, third and probably fourth ribs, with mild hemothorax on the right side; also an epiphyseal fracture of the left tibial tubercle. No foreign bodies were visible on either of the films. Fourteen hours after being wounded, under 1 per cent novocaine anesthesia, the 3-cm. wound of entrance just below the outer third of the right clavicle was excised. The tract entered and was traced below the pectoralis muscle, which was laid open. A small fractured piece of the clavicle was removed. The path of the fragment traveled posteriorly, anterior and superior to the axillary vessels and nerves and made a 3-cm. exit wound just medial to the posterior axillary line. The wound was widely excised and a large amount of clotted and liquid blood was evacuated. The tract led through the latissimus dorsi and



trapezius muscles but did not enter the chest cavity. Hemostasis was secured. Sulfanilamide was powdered over both the wounds and a vaselined gauze dressing was applied to the anterior wound. A paravertebral injection of 5 cc. of 1 per cent novocaine was done at levels of the cervical 7 thoracic 1, 2, 3 and 4 vertebrae. Five hundred cubic centimeters of blood were aspirated through the seventh intercostal space in the posterior axillary line and given as an autotransfusion, in addition to 500 cc. of normal saline. The wound of the left knee was then débrided. The patient's bronchial tree, which was filled with secretions, was sucked dry through a bronchoscope; he was returned to the ward in good condition. Four days postoperatively paravertebral block of the right dorsal 2, 3, 4 and 5 was done for relief of pain. No fluid was obtained on attempted aspiration. On the eighth postoperative day aspiration of the right thorax yielded 1,350 cc. of bloody fluid, and two days later 150 cc. of thin pink fluid was withdrawn. On the twelfth postoperative day aspiration of the right chest produced 725 cc. of thin pink fluid; thereafter the chest remained dry. On the twenty-second postoperative day the patient was ambulatory, but still had some loss of function of his right upper arm. He was evacuated to the rear with his chest in satisfactory condition.

#### FRACTURED RIBS

Of the large number of cases with simple and comminuted fractures of the ribs there were nine who had paradoxical breathing. Pain was controlled with intercostal nerve block. (In view of the fact that simple intercostal nerve block is so effective, we think it is most inadvisable to use adhesive tape to control pain in any chest injury.)

**Case 15.**—This patient was received at this hospital one hour after suffering injuries from a motorcycle accident which rendered him unconscious. Upon admission here he was dyspneic, cyanotic and experiencing extreme pain with paradoxical breathing. No chest perforation or sucking wound was apparent. There were fractures of the seventh, eighth, ninth, tenth and eleventh ribs, with hemothorax. One per cent novocaine injection of the seventh to eleventh intercostal nerves immediately relieved the pain, and stopped the paradoxical respirations. The patient was autotransfused with 500 cc. of blood on the first day following injury, 600 cc. on the fourth day and 250 cc. on the eleventh day, following which he was free of pain and evacuated to a convalescent hospital.

**COMMENT:** This case represents a simple, but gratifying means of treating a common injury, even in civilian life.

#### "BLAST LUNG" INJURIES

"Blast lung" injuries have been a relatively frequent finding, and a very discouraging condition. These cases typically present the following general points: (a) Proximity to a violent explosion such as a land mine; (b) multiple fractures; and (c) delayed respiratory-circulatory collapse, with marked pulmonary edema occurring two to three days after injury. No known therapy has been successfully employed in the treatment of these cases. Positive pressure oxygen therapy has been used with equivocal benefit. A case report, with pathologic findings is recorded below:

**Case 16.**—This patient was riding in the back seat of a command car when the rear wheel ran over a land mine. He recovered consciousness in a few minutes. He did not experience any dizziness, headache or blurring of vision, but did have difficulty in hearing in both ears. The latter might have been the result of a head injury which

caused a small puncture wound anterior to the left ear near the temporal artery. Speech and cerebation were not impaired. He was treated at a Collecting Station, and both legs and ankles were supported by wire splints extending above the knees. Under ether anesthesia, at a Field Hospital the wound of the right leg was débrided and plaster encasements were applied to both legs (the fracture of the left leg was not compound).

On admission to this hospital, 52 hours after injury, the patient was in good condition, with no complaints. The encasements on both legs were satisfactory, and the toes of both feet were warm. Four hours after admission the patient was conversing normally and rationally. His pupils were equal and regular. His pulse varied between 125 and 130. The following morning the pulse was 140, respirations 32, and blood pressure 98/50. Five hundred cubic centimeters of plasma were administered, after which the pulse was 120, respirations 40, and blood pressure 98/50. The patient had a temperature of 100.4° F., and was very drowsy, but mentally clear when aroused. There was no evidence of a head injury, except a small puncture wound above the left ear. Seven hundred and fifty cubic centimeters of plasma, 500 cc. of blood, and elevation of the foot of his bed brought the blood pressure up to 110 systolic. One and one-half hours later the blood pressure fell to 70 systolic. His respiratory distress was only moderate, although breath sounds were "spottedly" distant and coarse râles were heard throughout the entire chest. The patient was voiding involuntarily and spitting frothy blood.

The upper abdomen was distended, and no bruises or evidence of trauma to the abdominal wall were apparent. There was no peristalsis. Questionable consolidation of both bases with marked friction rub existed. A catheterized specimen of urine was clear. The same evening, at 1900 hours, the patient's condition became critical, with respiratory distress rapidly increasing. Two ampules of coramine and 500 cc. of blood were administered. Diminished breath sounds and tactile fremitus of the left chest with a loud to-and-fro friction rub was felt and heard. Dyspnea and slight cyanosis continued. Oxygen therapy was instituted. The blood pressure was 90/40, pulse 136, and respirations 26. There was a question of a pulmonary infarct. He expectorated frothy sputum with bright blood streaks, and breathed with difficulty and duress. He was lucid enough to attempt to answer questions. The abdomen was moderately distended. The patient struggled for breath (not obstructive type of dyspnea), then suddenly stopped breathing. Artificial respiration failed to revive him. He expired three days after sustaining injuries.

Autopsy revealed a clean peritoneum with no evidence of injury to the retroperitoneal tissues. The examination of the chest disclosed both pleural cavities intact, lungs expanded, grossly hemorrhagic, but crepitant in areas. There was some frothy serous fluid in the bronchial tubes on sectioning. There was no free blood in the pleural cavities. The pulmonary arteries contained thrombi, apparently postmortem. No injury to the thoracic cage was evident, nor was the diaphragm injured. The heart was grossly normal except for a questionable thrombosis in the auricle.

*Pathologic Diagnoses.—Gross:* (1) Compound fracture, right ankle. (2) Simple fracture, left ankle. (3) Blast injury, lungs (possible). (4) Thrombosis, pulmonary arteries (?). (5) Thrombosis, cardiac auricle (?).

*Histologic Examination.*—The lung shows extensive areas of intra-alveolar extravasations of red cells intermingled with varying numbers of pigmented macrophages. Occasional alveoli are filled with fluid containing a few red cells. The bronchial lumina contain large numbers of red cells. Interspersed with blood filled alveoli are occasional emphysematous alveoli, some with ruptured walls.

*Pathologic Diagnoses.—Microscopic:* (1) Pulmonary hemorrhage, severe, with ruptured alveoli. (2) Congestion of spleen. (3) Epicardial hemorrhage of the heart.

COMMENT: Some so-called "blast lungs" have had fat embolism. Characteristically, these patients also have had compound fractures, usually resulting from land mine traumatic amputations. Unfortunately, the special

fat stain was not used on this tissue. In view of the fact that there were ruptured alveoli we are obliged to classify this as a blast injury of the lungs.

## SUMMARY

A preliminary report is made on the management of 1,210 cases of wounds and injuries of the chest. Illustrative case records are presented. The following points are emphasized:

## A. Preoperative Recommendations:

1. Large occlusive vaselined gauze dressing over wound.
2. Whole blood for shock.
3. Immediate aspiration of hemothoraces (without air replacement).
4. Autotransfusion with thoracentesis blood.
5. Trocar-thoracotomy for pressure pneumothorax.
6. Intercostal nerve block.
7. Tracheal and bronchial aspiration.
8. Oxygen therapy.

## B. Operative Recommendations:

1. Endotracheal anesthesia.
2. Intravenous fluids, preferably blood, flowing in one or two veins, during operation.
3. Permissible to enlarge débrided sucking wound for exploration of diaphragm or the control of hemorrhage.
4. Conservative surgery, minimizing the importance of foreign body removal, unless it is large, accessible, or in a vital organ.
5. Formal thoracotomy: (1) To control hemorrhage. (2) To close large, bronchopleural fistula. (3) In known or suspected thoraco-abdominal lesions. (4) In known or suspected esophageal lesions.

## C. Postoperative Recommendations:

1. Bronchial aspiration (catheter or bronchoscopic).
2. Aspirate all air immediately postoperatively.
3. Repeat intercostal nerve block.
4. Continue nasal oxygen if dyspneic.
5. Penicillin 25,000 units every three hours intramuscularly.
6. Encourage cough, with breathing exercises.
7. Daily or necessary thoracenteses without air replacement.
8. Evacuate when transportable.

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## EARLY PULMONARY DECORTICATION IN THE TREATMENT OF POSTTRAUMATIC EMPYEMA

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OF ALL THE TRAGIC SEQUELAE OF WAR, few are more distressing than the problems of those whose injuries result in chronic intrapleural sepsis. These unfortunates are inevitably found in large numbers through the post-bellum years either doggedly submitting to one major operative procedure after another, or resignedly suppurating through a shortened life-span of chronic invalidism.

Surgeons interested in thoracic disease have long been mindful of the magnitude of the problem of chronic empyema and have been prodigious in their efforts toward its solution. Despite many notable contributions elucidating many of the factors concerned in the inception of chronic empyema, it still occurs all too frequently following injury to the thorax. An examination of the voluminous literature on the subject brings out the striking fact that empyema is thought of and written about, for the most part, as though all empyemas were of the same generic type. Posttraumatic empyema certainly gives rise to a far higher incidence of chronicity than does meta- or post-pneumonic empyema. Yet little effort is made in the literature to establish vital, fundamental differences. The inference is too often left that empyema thoracis is empyema thoracis, regardless of its mode of origin. Yet significant differences do exist and must be recognized if we are to approach properly the posttraumatic empyema problem. That this difference was not more clearly recognized and emphasized by those who studied the large number of empyemas during World War I is remarkable. Perhaps the correct explanation is Churchill's<sup>1</sup> suggestion that the influenzal empyemas so overshadowed the posttraumatic cases in numbers and in interest that the individuality of the latter group was not recognized.

Despite modern surgical therapy and various chemotherapeutic adjuncts it now seems clear that no less than 15-20 per cent of those receiving penetrating and perforating thoracic wounds in this war will develop posttraumatic empyema<sup>2</sup>. When one contemplates the global scale of this conflict, and the probable total number of casualties, one becomes aware of the unprecedented chronic empyema potential that exists. The value of any method of treatment that will minimize the occurrence of chronic, crippling intrapleural infection following wounds of the chest is readily apparent.

This paper is a presentation of what we believe to be the most rational

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and effective method of treating posttraumatic empyema and represents the most productive approach, we believe, toward the prevention of the chronic phase of that disease. We are aware that much of this represents a radical departure from time-honored concepts.

In any study of posttraumatic empyema one is struck by the importance of the presence of blood in the pleural cavity as the antecedent factor. Much of the knowledge that we have gained pertaining to posttraumatic empyema has stemmed directly from a study of the problem of hemothorax. The vast majority of posttraumatic empyemas are infected hemothoraces, and the present rationale of treatment represents the direct application of those principles learned in dealing with hemothoraces both clotted and unclotted. Since

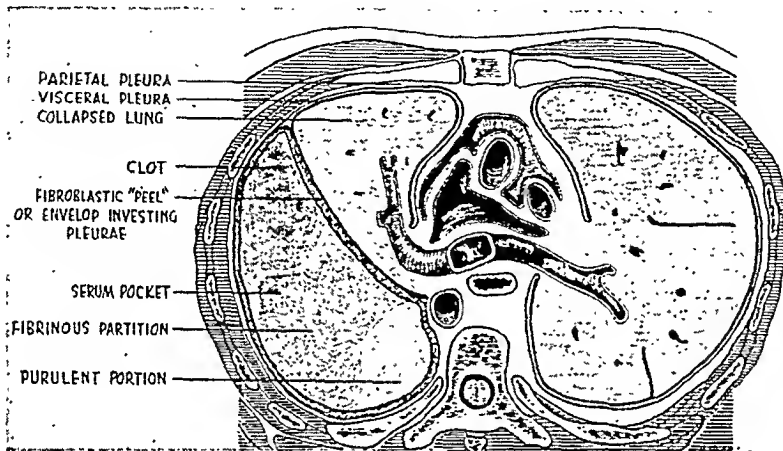


FIG. 1.—Photograph of diagram of cross-section of chest, with an infected organizing hemothorax of the left side.

the vast majority of posttraumatic empyemas develop on a basis of an hemothorax, the nature of the empyema can best be understood by an inquiry into the pathology of that entity. Studies of the intrapleural changes in hemothorax have been remarkable chiefly by their absence. The thoracoscopic examination of the pleura in cases of hemothorax by Edwards and Davies<sup>3</sup>, in 1940, represents one of the first serious efforts to ascertain the nature of the pleural response to blood in the pleural cavity.

The opportunity to operate upon and decorticate the lung of a case of clotted, organizing hemothorax, by one of us (T. H. B.) during the African Campaign, led to a recognition of the essential pathology of hemothorax and to a study of a large group of similar cases. This experience has yielded much valuable and applicable information.

As has been pointed out in a recent paper by Samson, Burford, Brewer and Burbank<sup>4</sup> all hemothoraces are associated with very typical and definite changes within the pleural cavity of greater or lesser degree. The essential feature is the formation of a fibroblastic membrane or "peel" over the visceral and parietal pleurae. This membrane forms a sac or envelope within which the hemothorax is contained. The relationship of this hemothoracic envelope to the visceral and parietal pleurae can be readily visualized by consulting

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Figure 1. This membrane forms from the deposition of fibrin on the pleural surfaces. Red blood cells are caught in the fibrin meshes and a definite "peel" very early takes form. This layer begins to undergo rapid active fibroplasia and angioplasia, and one can soon recognize an "older" side toward the pleura and a "younger" side toward the hemothorax. From the pleural side of the fibroblastic membrane, fibroblasts wander out toward the younger portion and nests of angioblasts rapidly give rise to capillaries. The transition to adult fibrous tissue is prompt, and by three weeks the cellular pattern of the "peel" is well defined. Figure 2 shows the cellular pattern of a three

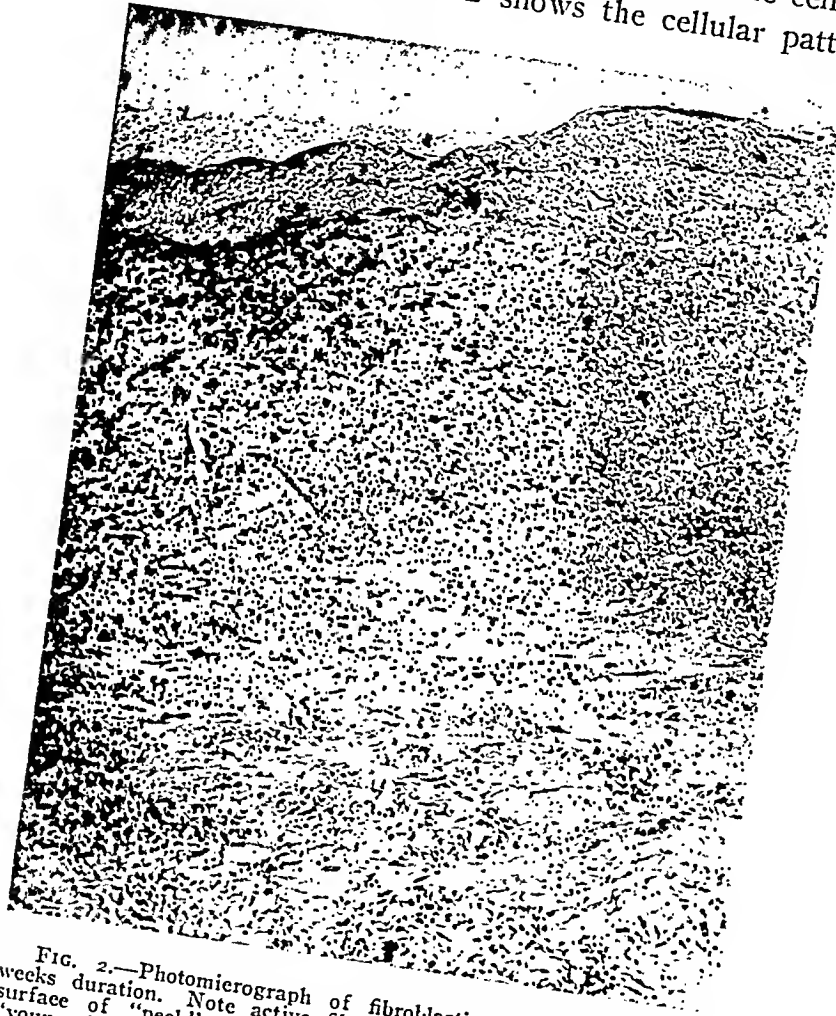


FIG. 2.—Photomicrograph of fibroblastic membrane of three weeks duration. Note active fibroplasia proceeding from pleural surface of "peel," which is at bottom of figure toward the "younger" portion at top of figure. (X100)

week "peel," and shows the fibroblastic nature of the membrane. As the process grows older the cellular intimacy between membrane and pleura becomes greater until by eight or nine weeks the majority of cases will present definite symphysis. Until this time the pleura remains remarkably normal, and a cleavage plane between "peel" and pleura is easily established. Forming in the presence of a collapsed or partially collapsed lung, this membrane maintains the collapse of the lung and forms the chief deterrent to its reëxpansion. Figure 3 is a photograph of portion of a typical fibroblastic membrane removed from a case of posttraumatic empyema.

Hemothorax represents the largest hematoma with which the body has to deal. It is for the most part far too large to vascularize rapidly, and this fact may very well play a rôle in its tendency toward infection. This is particularly true of a clotted one which cannot be aspirated. In a liquid hemothorax prompt aspiration with pulmonary reëxpansion results in a cessation and a resolution of the changes described. If infection supervenes in either the liquid or the clotted hemothorax the resulting empyema will be unique in two respects. First, the lung is collapsed and compressed to a greater or lesser

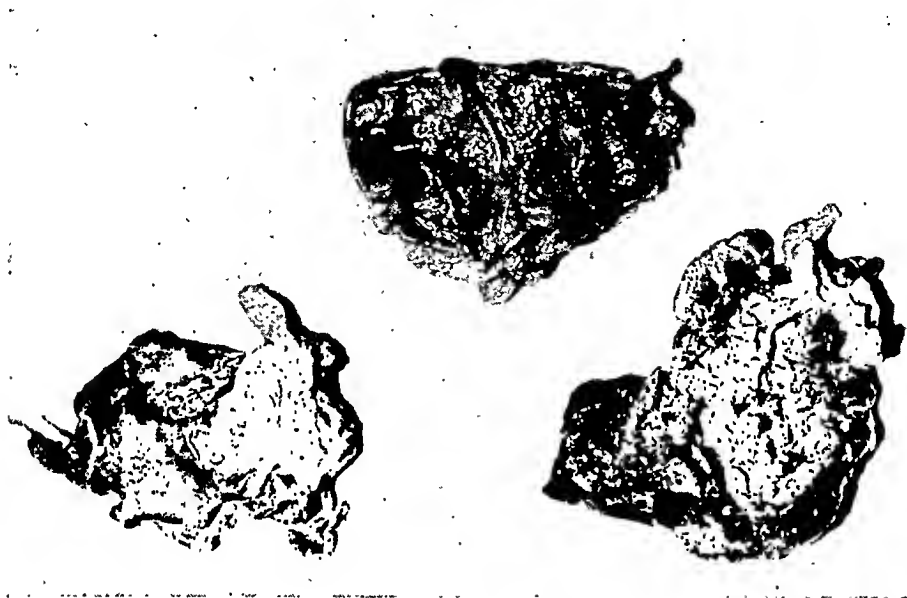


FIG. 3.—Photograph showing gross appearance of three-week-old fibroblastic membrane, or "peel," removed from visceral pleura of a case of empyema supervening upon an organizing hemothorax.

degree by the intrapleural blood even before infection occurs. Second, there rapidly develops, as described above, a constrictive pulmonary investment which restrains pulmonary reëxpansion. The recognition of these two factors is of prime importance in formulating a rational effective therapeutic approach to the problem of the empyema of trauma. Such a concept embodies not only evacuation of the pleural contents but also pleural divestment which will result in immediate and total primary pulmonary reëxpansion and complete obliteration of all pleural "dead space."

Fowler,<sup>5</sup> in 1893, and Delorme,<sup>6</sup> independently, in 1894, were the first seriously to attempt pulmonary mobilization in chronic empyema, by decortication. That the operation was so rarely successful was due to the fact that it was not attempted until late in the disease when, as we have seen from the discussion above, a complete fusion existed between pleura and the fibroblastic membrane. That the original attempts to perform decortication were made only upon patients who had been infected for many weeks, and often months, is understandable. To operate in the presence of pus without the advantages of bacteriostasis would have been inadvisable. These workers

were forced to adequately drain the empyema and await partial cavity sterilization. The idea of operating upon the acute phase of empyema was not to be considered in that time. Hedblom's<sup>7</sup> series of 30 cases, with 20 cures and one operative death, was the best reported but was not equaled by others. Decortication, except for the isolated instance, fell into disrepute and procedures designed to collapse the chest wall in upon the lung and thus obliterate the empyema cavity were devised. These procedures were admittedly serious compromises with the ideal and in no sense were restorative of function.

The operations of Schede,<sup>8</sup> Estlander,<sup>9</sup> the discussion procedure of Ransohoff,<sup>10</sup> and various combinations of these with partial decortications, such as the operation of Keller,<sup>11</sup> became the accepted operative approach to chronic empyema. The operative mortality remained high and the road to a cure for the patient remained a long hard one.

Samson and Burford (*loc. cit.*) in the course of a rather extensive experience in the decortication of large organizing hemothoraces were able to study a group of 15 early posttraumatic empyemas treated by decortication. Part of these were found to be infected at operation, when locules of pus were found within the hemothoracic cavity (see Figure 1) and when the case had been submitted to operation in the belief that a noninfected organizing hemothorax was being dealt with. A few were purposely operated upon immediately after obtaining positive smears or positive cultures upon examination of the fluid obtained by thoracentesis. The remainder were known massive empyemas submitted to decortication after preliminary rib resection drainage with attempts to sterilize the cavity. No case of known, frankly purulent, posttraumatic empyema was submitted to primary thoracotomy with decortication. The results in this group were encouraging. Of the 15, five obtained a prompt cure, five were markedly improved but retained rather small basal empyemas, and in the remaining five, large empyemas persisted but the cavity was smaller than the original process.

The advent of penicillin into this Theater and the contributions of Lyons,<sup>12</sup> which have so significantly influenced the handling of wound sepsis in general, stimulated the present study.

Penicillin, with its known property of bacteriostasis and, thus, of diminishing the danger of invasive infection when operating in the presence of acute infection, seemed to us to be the awaited, necessary adjunct to render safe the early application of more effective methods to the therapy of pleural sepsis. The pursuance of a rational plan of treatment in posttraumatic empyema directed toward achieving early pleuropulmonary lysis, total ablation of infected tissue, complete primary pulmonary reexpansion, with absolute obliteration of residual pleural "dead-space" relatively free from the danger of septic dissemination, at last seemed safe and applicable.

#### DESCRIPTION OF CLINICAL MATERIAL

In March, 1944, we began subjecting all suitable cases of posttraumatic



empyema to thoracotomy, with decortication after an initial period of penicillin preparation. Twenty-five such cases have been treated by this method since then. The majority of the cases in this series have been treated at a Thoracic Center in the North African Theater of Operations. This paper represents an account of that experience. All cases in this group were definite empyemas. In two, however, there was failure to obtain positive cultures from the pleural pus. This is not a higher incidence of failure to obtain growth from pus than one would encounter in any series of 25 cases of empyema, particularly since the use of the sulfonamides and penicillin is so widespread. All had clinical evidence of infection: *viz.*, fever, anorexia, malaise and the clinical appearance of toxicity. The majority were acutely and severely ill. At operation, all had definite pus in the pleural cavity.

The selection of cases was in the direction of leaving the less severe ones to be handled by simple rib resection drainage, and choosing those with the more complete types of empyema; *i.e.*, those most likely to develop chronic empyema. If the empyema was total, or if the apex was involved in the collapse, the case was selected for thoracotomy with decortication. Sizeable (above 1.5 cm. in greatest diameter) intrapulmonary foreign bodies were considered important reasons to perform thoracotomy-decortication procedures when the empyema was less than total. Intrapleural foreign bodies were considered an even more important indication for operation. Failure of the lung to reexpand progressively and quickly (within four weeks) after adequate rib resection drainage was also considered a most important indication to open the chest and decorticate the lung.

Though we feel that thoracotomy with decortication without preliminary drainage to be the method of choice a few cases in any series will be too sick initially to withstand major surgery. In these, of course, a preliminary rib resection drainage will be necessary. Eight of the 25 cases in this series presented this type of problem.

For the small basal empyemas as well as for the smaller encapsulated empyemas in other regions of the thorax we believe properly placed drainage to be the method of choice. These seldom give rise to persistent cavities if properly drained.

All the cases were males between the ages of 18 and 30.

The essential data on these 25 cases is summarized in Table I. Complete case records of Cases 6 and 22 are included, and are representative of the series.

#### REPRESENTATIVE CASE RECORDS

**Case 6.**—This patient sustained severe multiple penetrating shell fragment wounds of the right thorax, right arm, and right thigh on March 26, 1944. First aid was administered immediately by the Company Aid Man, and the patient promptly moved to the Aid Station, where plasma and morphia were given. Within 12 hours of wounding he was admitted to a Forward Evacuation Hospital, where all wounds were débrided and the patient transfused. The patient was again wounded when the hospital

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was bombed, suffering a severe laceration of the scalp from a bomb fragment. This wound was débrided and sutured. Signs of right hemothorax were increasingly apparent and a thoracentesis was performed March 31, 1944, which yielded 1,100 cc. of serosanguineous fluid. Thoracenteses were repeated on April 1 and April 5, yielding 1,050 cc. and 1,000 cc. of similar fluid, respectively. On April 9, patient was admitted to the Chest Center in the Base. Examination revealed a moderately febrile patient, who appeared acutely ill but in no significant respiratory distress. Signs of intrapleural fluid were present on the right. A healing scalp wound and an infected wound of the right thigh were present. The débrided wounds of the right arm and right thorax were clean and granulating. A thoracentesis, performed April 9, returned 750 cc. of dark bloody fluid with an offensive odor. Cultures were made of this fluid. Six hundred fifty cubic centimeters of similar fluid were removed on the following day and on April 11, 625 cc. were obtained. On April 12, cultures of the previously obtained pleural fluid were reported positive for *Clostridia*. Systemic penicillin was begun on this date, the patient being given 25,000 units intramuscularly every three hours. The temperature at this time was running from 101° to 102° F., rectally. The patient appeared mildly toxic and was anorexic. On April 13, the fluid from the right chest was even more offensive and showed early purulent transition. A roentgenogram of the chest showed a marked intrapleural process on the right side, with considerable pulmonary collapse, the apex being compressed to the level of the fifth rib posteriorly. An intrapleural metallic foreign body could be visualized (see Figure 7A). The institution of penicillin therapy did not result in any reduction in fever but did seem to bear favorably upon the patient's appetite and general condition. Specimens of pleural fluid continued to become progressively more purulent, and the organism was identified as a definite pathogenic proteolytic *Clostridium*. Repeated blood transfusions were given, bringing the patient's red blood cell volume up to 40. On April 18, 1944, 23 days after injury, and after six days on penicillin protection, immediately following excision and suture of the wound of entry, a thoracotomy with evacuation of the pus, and decortication of the lung was performed. A right posterolateral incision was made and the pleural cavity entered through the sixth interspace. A large hemothoracic envelop was found containing a large amount of very foul-smelling pus, liquefying blood clot and fibrin. A metallic foreign body was found lying free in the empyema cavity. No fistulae were present. The lung was collapsed an estimated 75 per cent. The pus was aspirated, the cavity cleansed with saline irrigations, and a line of cleavage readily found between the visceral pleura and the fibroblastic membrane. The latter measured 4 mm. in thickness (see Fig. 3). This membrane stripped readily from the pleura and the entire lung decorticated easily. After decortication, the visceral pleura presented an entirely normal appearance. Once this has been accomplished the lung reexpanded completely, filling the chest and obliterating all pleural "dead space." No leaks were present in the lung. The pleural cavity was again irrigated with physiologic saline solution and an internal intercostal nerve block with 1 per cent novocaine done. Anterior and posterior intercostal "water-seal" catheters were placed, the former in the second interspace in the midclavicular line, and the latter in the eighth interspace in the posterior axillary line. The chest was then closed, using silk throughout. Twenty-five thousand units of penicillin in 100 cc. of sterile water were injected into the chest through the catheters and the catheters clamped. Fifteen hundred cubic centimeters of whole blood were given during the operation. The patient was bronchoscoped at the completion of the operation. Following operation the posterior catheter was left clamped for six hours to allow the penicillin to remain within the pleural space. The anterior catheter was connected to a "water-seal" bottle to permit the egress of trapped air.

The postoperative course was entirely uneventful. Defervescence was prompt, the temperature reaching normal on the fifth day, and remaining so. The anterior catheter was removed on the second postoperative day. The wound healed without infection, and

the sutures were removed on the seventh postoperative day, at which time the patient was allowed up. Penicillin was discontinued on the eighth postoperative day. The patient's convalescence was rapid and a roentgenogram made three weeks after operation showed a clear chest, with a completely expanded lung (see Fig. 7B). He was discharged to full duty, completely cured on June 5, 1944, only 70 days after injury. We have since learned that he accompanied his combat outfit in a recent amphibious operation.

**Case 22.**—This patient suffered a penetrating shell fragment wound of the left thorax on June 1, 1944. He was given almost immediate resuscitation and within 20 hours of injury had been admitted to a Forward Evacuation Hospital, where intercostal nerve block, thoracentesis and débridement of the wound of entry was done. Thoracentesis on June 2 was productive of 300 cc. of bloody fluid and, on June 3, 750 cc. of similar fluid were removed. On June 5, 500 cc. were obtained, and at this time it was noted that the fluid had an early purulent character. The patient was admitted to the Chest Center June 6, 1944. Upon admission, he was acutely ill, slightly cyanotic and moderately dyspneic. The temperature was elevated, and patient appeared toxic. Roentgenograms of the chest showed an extensive left-sided intrapleural process, with apical collapse, and an intrapulmonary metallic foreign body (see Fig. 12A). Thoracentesis yielded 250 cc. of thin sanguino-purulent material, with a foul odor. A culture of this was positive for proteolytic *Clostridia*. On June 7, 1944, systemic penicillin was started, 25,000 units being given every three hours. Daily blood transfusions of 500 to 1,000 cc. were given. Thoracotomy with decortication was performed June 8, 1944, one week after injury. A left posterolateral incision was made and the pleural cavity entered through the sixth interspace. A large empyema cavity was found. This was filled with thin, malodorous pus. A fistula, two centimeters in diameter, was present in the base of the upper lobe at the fissural margin. Investigation of the fistulous opening showed it to communicate directly with a pulmonary abscess, four centimeters in diameter, with the lung in the collapsed state. The metallic foreign body, an irregular piece of shell casing, 1.9 cm. in its largest diameter, was found lying free in the abscess cavity. The empyema cavity was aspirated free of pus and fibrin masses, and the "peel" decorticated from the visceral pleura. The "peel" stripped off readily, leaving a normal glistening visceral pleura. The lung reexpanded to fill the hemothorax. A laceration extending into the abscess, presenting a fistula in the upper lobe, was enlarged and the foreign body removed. The lining of the cavity was débrided by sharp dissection down to normal lung tissue. The defect in the lung was then closed in layers. Intercostal nerve block with novocaine of nerves three to nine, inclusive, was done, and the anterior and posterior intercostal catheters placed, as described in Case 6. The chest was closed in layers, using fine, interrupted silk sutures. Twenty-five thousand units of penicillin in 100 cc. of sterile water were introduced into the pleural cavity through the catheters and the catheters clamped. The patient was bronchoscoped at the conclusion of the operation. Fifteen hundred cubic centimeters of blood were given during the procedure. On being returned to bed the anterior tube was connected to a "water-seal" bottle, the posterior tube being left clamped for six hours. Despite the extensive operative procedure the patient manifested very little postoperative reaction and the temperature and pulse returned to normal on the seventh postoperative day (see Fig. 6). The temperature rise on the ninth postoperative day corresponded to the removal of the posterior intercostal tube. The anterior catheter had been removed on the third postoperative day. The temperature and pulse remained normal, and the wound healed without infection. The patient's return to normal activity was rapid. A roentgenogram three weeks after operation showed a completely expanded lung and no intrapleural abnormalities (see Fig. 12B). The patient was discharged to full duty on July 28, 1944, eight weeks after injury, and participated in an amphibious operation within a short time after discharge.

PREOPERATIVE MANAGEMENT

Once the diagnosis of infection within the pleural space was established it was necessary to decide whether or not the case was one that could be handled best by thoracotomy with decortication, or whether simple rib resection drainage was the procedure of choice. It is our definite feeling that it is wisest to perform simple rib resection drainage in those cases where the pleural infection is limited to the basal portion of the thorax or where it is small and encapsulated. A few cases will be too sick initially to subject to the more radical procedure of open thoracotomy, with decortication, and in these a preliminary rib resection and drainage will be necessary. If cavity obliteration and pulmonary reëxpansion was not prompt and satisfactory the case then became a candidate for decortication. Needless to say, proper roentgenologic and laboratory studies had been made to establish an accurate picture of the patient's general condition with reference to pulmonary status, total protein and hematocrit. Studies of the pleural fluid identified the offending micro-organism, and the roentgenograms disclosed the presence of intrathoracic foreign bodies, gave evidence of bronchopleural fistulae, or other lesions.

As soon as evidence of intrapleural infection had been obtained, penicillin therapy was instituted, giving 25,000 units of penicillin every three hours—a total of 200,000 units every 24 hours. Daily transfusions of 500 to 1,000 cc. of whole citrated blood were given until the plasma proteins were restored to a normal level, and until the hematocrit values reached a normal of 40 per cent, or slightly above. The length of time that penicillin was given prior to operation was not uniform. Some patients did well when only 24 hours elapsed from the institution of penicillin therapy until operation. Others, for one reason or another, have been kept on the drug for as long as 17 days before being submitted to operation. It would seem that 48 to 72 hours would be a reasonable and rational period of preoperative penicillin therapy, before undertaking thoracotomy with decortication. Experience has taught that it is useless to await a defervescent phenomenon. That comes only with extirpation of the infected focus.

OPERATIVE TREATMENT

Endotracheal gas-oxygen-ether anesthesia was used in all cases. Unhealed wounds of the affected side were either closed secondarily, or excised and closed, using a separate set of instruments. If the wounds were too badly infected to be closed, or to be excised and closed, they were carefully isolated from the field of incision. In cases where a previous operation for drainage had been performed the drainage site was isolated and dealt with at the time of closure.

A posterolateral incision was made on the affected side just below the angle of the scapula, and the pleural cavity was entered through the sixth interspace in the majority of cases. Occasionally the fifth or the seventh

interspace was chosen, depending somewhat upon the thoracic habitus of the patient but more particularly upon whether one anticipated having to do more at the upper pole or more at the lower pole of the involved hemithorax. The great majority of the operations were performed without costal section or resection, although, in a few, previous operations or comminuted fractures of the ribs made it wise to resect all or part of a rib. Exposure is entirely adequate without costal mutilation and intercostal incision is the method of choice. Upon entering the pleural cavity it is extremely important to free the lung rather widely in all directions from the parietal pleural "peel" if it is adherent in the vicinity of the opening into the chest. If this precaution is not taken extensive damage will befall the lung when the ribs are spread. Since the "peel" on the parietal pleura is to be left it is important to bear in mind during this process of para-incisional mobilization that the proper line of cleavage lies between the two layers of fibroblastic membrane, *i.e.*, the one on the visceral pleura, and the other on the parietal, and not between either pleura and its respective "peel." This relationship can be readily visualized by an examination of Figure 1, where these layers are diagrammatically illustrated. Once this maneuver has been accomplished, rib spreading retractors are introduced and the ribs gradually spread to give exposure. It is important to widen the blades of the retractors gradually to allow for muscular relaxation so that fractures of the ribs, muscular avulsion or pleural tears will not occur.

Pus, clot fragments, and fibrin masses are cleansed out of the empyema cavity and the cavity examined for bronchopleural fistulae. If none exist it is well at this point to thoroughly wash out the empyema cavity with sterile physiologic saline. Decortication of the fibrino-fibrous investment on the visceral pleura is then begun by carefully incising it down to the visceral pleura. This maneuver is materially aided by having the lung "braced," as it were, against the incision by moderate positive pressure inflation. The moment the "peel" is completely disrupted in any segment the underlying lung will, if under positive pressure, immediately herniate through the incision, thus, accurately delineating the desired cleavage plane. The edge of the membrane is then grasped with forceps and the actual decortication begun. This is best done by gently and carefully dissecting with a small, firmly packed gauze "pusher." Particular care not to tear the lung must be exercised at the fissural margins and around fistulae, or healed areas that represent points of entrance or exit of a missile. When the visceral pleura has been completely decorticated the lung should be brought to full re-expansion and the surface carefully examined for tears in the visceral pleura and/or parenchyma. These, if present, are repaired by interrupted sutures of fine silk. Fistulae, if present, are best treated by freshening their margins and closing them with sutures of fine silk.

On three occasions in this series it has been necessary to deal with pulmonary abscesses at the time of operation (Cases 7, 21 and 22): We have elected to open the abscess completely, débride the necrotic lining membrane

by sharp dissection and close the defect in the lung with two or more layers of fine silk in such a fashion that all dead space was obliterated.

It will occasionally be found that after what may be termed the "primary" peel has been removed there will remain small scattered islands of a very thin, but surprisingly tough secondary membrane still adherent to the visceral pleura. These will be observed to be causing creasings and infoldings of the lung that materially hampers 100 per cent reëxpansion, and must be meticulously removed.

If an intrapulmonary foreign body is present of such a size as to warrant removal, there should be no hesitancy in opening the lung, extracting the missile and repairing the lung with fine silk.

No attempt is made to remove the membrane from the parietal pleura. It is mandatory, however, to see that a completely smooth margin is left around the entire circumference of the reflection of the peel from the parietal to the visceral pleura. Cuffs and strands of the unattached membrane can only serve as potential sites for the pocketing of secretions.

The diaphragm will be found almost universally elevated and fixed. While there is no need to decorticate it, yet it is felt wise to free this structure circumferentially and thus mobilize it. Note is made of the costophrenic and cardiophrenic sinuses to see that they are free of clot and membrane.

The entire internal chest wall is inspected and palpated for the presence of rib splinters, or metallic foreign bodies which partially protrude into the chest. If present, these are removed and a smooth surface achieved.

Every effort is directed during the entire procedure to achieve complete pulmonary reëxpansion and complete obliteration of intrapleural "dead-space." Any compromise with this ideal is a certain step toward failure. The operation that ends failing to bring the lung into absolute contiguity with the chest wall, and/or that fails to make certain that it remains there has failed to achieve its purpose, and has little likelihood of succeeding. It is a fallacy to assume that half measures in this direction will, by the generous intervention of providence, or something equally unlikely, result in a cure.

Provision for the maintenance of pulmonary expansion is made by the insertion of two, and frequently three intercostal tubes which are subsequently connected to "water-seal" bottles. One of these is placed in the eighth interspace in the posterior axillary line. This tube is a fenestrated piece of soft rubber clysis tubing of 10-mm. internal diameter. It is carried into the pleural space for a distance of two and one-half to three inches, and its proximal end tacked to the parietal pleural "peel" with one silk suture. For the second tube a small Pezzar catheter (No. 12 or 14) is used, the tip being cut off so that just a flange remains. This is brought out through the second interspace anteriorly in the midclavicular line. If the third tube is employed, it is of the same type as the second, and is brought out through either the fifth or sixth interspace in the midclavicular line. The tubes are clamped temporarily. It may be pointed out here that tubes within the pleural cavity are not, and do not, act as foreign bodies *per se*. They only become that

when they cease functioning in their all-important capacity of maintaining pulmonary expansion, and obliteration of pleural "dead-space." When they cease to facilitate progress in that direction, then, and only then, do they become foreign bodies, and should be removed promptly. If the case has been one in which a previous rib resection for pleural drainage has been performed it is altogether likely that the drainage site will correspond with the site of election for the posterior tube. In these cases we have excised the margins of the wound for preliminary drainage, placed the tube through it, and sutured about the tube so that it was air-tight. Any coincident chest wall defect must be freshened and closed solidly.

Intercostal nerve block with 1 or 2 per cent novocaine is done at this time, blocking two or three nerves above the interspace of entrance and two or three below.

A final copious lavaging of the pleural cavity with sterile physiologic saline is carried out, and the cavity aspirated completely dry. A final inspection is made to assure that a completely clean field is being left. The lung is then brought gradually to full expansion. When the lung is completely out to the chest wall the closure is proceeded with. We have used interrupted silk sutures exclusively. Pericostal sutures are not used.

When the closure has been completed 25,000 units (occasionally 50,000) of penicillin in 100 cc. of physiologic saline are injected into the cavity through the tubes, an equal amount being allocated to each tube. The one or two anterior tubes are immediately allowed to drain under water, but the posterior tube is left occluded for six hours following operation to prevent the escape of the penicillin solution. The patient is bronchoscoped before leaving the table.

Blood is given during the operation, a total of 1,000 to 2,000 cc. being administered during the procedure. Having brought the patient to the operating room with a normal hematocrit it is just as important to have him enter the reparative phase of his course with the advantage of a full complement of red blood cells, hemoglobin, and plasma protein. This aspect is no less important than the shock-prevention function of blood replacement in the end-result.

#### POSTOPERATIVE MANAGEMENT

Following the return of the patient to the ward he is placed on his back with the bed level. As soon as the patient has fully reacted, the back rest is elevated and the patient is instructed to breathe deeply and cough at intervals. Morphine is administered as required. Food is permitted, as tolerated, and intravenous fluids are given as indicated. One or two transfusions during the first two or three postoperative days are usually given, depending upon the hematocrit. Systemic penicillin is continued until the tubes are out and the patient has been afebrile for two or three days. The tubes are checked frequently to assure their proper functioning. The anterior catheter is removed as soon as apical expansion has been obtained, and there is no

further oscillation of the water column on cough. This is usually a matter of 48 to 72 hours. The posterior tube is left as long as there is any serous drainage through it. This will vary rather widely. The majority may be safely removed between the seventh and tenth postoperative days.

In the event that a complete cure does not occur, and the patient develops a basal empyema, a two-inch section of rib is removed (usually the eighth) in the posterior axillary line and a large rubber tube introduced and made air-tight. This is connected to a "water-seal" bottle. Procrastination in providing adequate drainage, once a recurrence of the empyema has occurred will inevitably result in a more extensive cavity forming than if proper drainage is promptly instituted.

Sutures are removed on the sixth or seventh day and the patient allowed up. A return to full activity is encouraged as rapidly as is consistent with the patient's strength. Deep breathing and postural consciousness are stressed. Shoulder and arm motion of the operated side are encouraged very early in the postoperative course.

#### RESULTS

Nineteen of 25 cases obtained primary cure of the empyema. Six of the 25 developed a small recurrent basal empyema. The only deviation from 100 per cent *per primam* wound healing in the entire series was a trivial superficial wound infection which occurred in Case 1. The fever in all instances subsided promptly. Postoperative reactions were remarkably mild. No case developed any evidence of embolic infection during the period of time they were under our observation. To date we have no knowledge of the occurrence of any such complication in any case. The one death in the series occurred eight weeks postoperatively, and cannot be considered an operative death (Case 25).

#### COMPLICATIONS

Complications have been gratifyingly few. In the 25 cases all wounds healed solidly and *per primam*. In only one case (Case 1) was there any wound sepsis. This was a simple superficial wound infection which cleared promptly. In six instances there was a basal recurrence of the empyema requiring secondary thoracotomy with rib resection. In all, the empyema was much less than the original process and in only one patient is there any likelihood that a further obliterative procedure will need to be undertaken to effect a cure. The one death in the series presented a recurrent empyema, recurrence of multiple bronchopleural fistulae, and bronchopneumonia of the contralateral lung. In Case 21, there was reopening of the abscess and a recurrence of the empyema. This remained localized to the apex and was very much less in extent than the involvement at thoracotomy.



## DISCUSSION

We feel that the valid applicability of early reparative surgical measures to the problem of traumatic pleural infection has been demonstrated. In addition to the importance of the early cure of the infection, the complete restoration of pulmonary function as rapidly as possible is clearly of vital importance. Before the present concept could be evolved and applied it was first necessary to demonstrate certain fundamentals. The first of these, the essential nature of the pathology of posttraumatic empyema, grew out of a study of the pathology of hemothorax. The demonstration of the fibroblastic membrane investing the pleurae was tantamount to an understanding of most of the problems involved in the treatment of posttraumatic empyema. This discovery led to the realization of what must be accomplished if a prompt cure was to be obtained. It, likewise, explained many of the cases of chronicity and clearly pointed the course to their prophylaxis. The demonstration of the efficacy of penicillin to control bacterial invasiveness and to thus render surgery safely applicable at the optimum time to obtain the maximal functional result (Lyons, *loc. cit.*), was the second of these fundamentals.

In this series of 25 cases of posttraumatic empyema treated by thoracotomy with decortication, under penicillin protection, there has been no favorable selection of cases. The cases have been representative (Table I). All were clinically ill. All had definite empyemas. In the main, they represent the more severe and complicated types. This was inevitable, since as pointed out in the discussion of the selection of cases, those with only basal or small encapsulated empyemas were treated by rib resection drainage alone. The fact that three cases of associated pulmonary abscess were encountered in the series will demonstrate the fact that favorable cases were not selected. The term pulmonary abscess as used here perhaps requires further description. The abscesses represented, in fact, seriously infected lacerations with cavity formation and suppuration.

An examination of Table I will reveal that the series may be divided readily into two groups. The first group of 18 cases presented only pleural involvement. The second group (seven cases) had in addition to pleural infection, significant pulmonic pathology including three cases of pulmonary abscess associated with metallic foreign bodies, bone fragments, and clothing. This distinction is important in an analysis of the results. Of the 18 cases having no significant pulmonic pathology there were 16 cases of primary cure. The use of the word "cure" indicates that the lung fully expanded and completely obliterated the pleural cavity, and that there was no clinical or roentgenographic evidence of a persistence or recurrence of the empyema during the period of postoperative observation varying from six to ten weeks. In all of the 19 cases classed as cured, the complete obliteration of the pleural space and the disappearance of evidence of infection had taken place within two weeks after operation. Of the two in this group that developed a re-

# LUNG DECORTICATION IN EMPYEMA

TABLE I  
SUMMARIZED DATA OF CASES

Case No.	Type of Injury	Time from Admission to Base Hospital	Time from Injury to Operation in Days	Type of Hemothorax	Etiologic Organism of Empyema	Previous Surgical Therapy	Associated Thoracic Pathology at Time of Definitive Therapy	Definitive Therapy	Result
1.	SFW pen. left	26 days	28 days	Liquid	Hemolytic <i>Staphylococcus</i>	Débridement. Thoracentesis. Secondary closure	Metallic foreign body, left lower lobe.	Penicillin protection 24 hours. Thoracotomy with decortication. Local penicillin. Penicillin 11 days postoperative	Superficial localized wound infection cleared promptly. Complete primary cure.
2.	SFW pen. right	10 days	35 days	Clotted	Hemolytic <i>Staphylococcus aureus</i>	Débridement. Thoracentesis. Celiotomy. Secondary closure	Metallic foreign body, right lower lobe	Penicillin protection 24 hours. Thoracotomy with decortication, removal metallic foreign body from lung. Local penicillin. Penicillin 10 days postoperative	Complete primary cure. No complications.
3.	SFW pen. left	30 days	28 days	Clotted	Hemolytic <i>Staphylococcus albus</i>	Débridement. Thoracentesis. Secondary closure	Metallic foreign body, left lower lobe. Comminuted fracture 7th rib left	Penicillin protection 24 hours. Thoracotomy with decortication, removal metallic foreign body from lung. Local penicillin. Penicillin 10 days postoperative	Complete primary cure. No complications.
4.	SFW perf. right	32 days	42 days	Liquid	Hemolytic <i>Streptococcus</i>	Débridement. Rib resection drainage. Secondary closure	None	Penicillin protection 48 hours. Thoracotomy with decortication. Local penicillin. Penicillin 12 days postoperative	Complete primary cure. No complications.
5.	SFW pen. right	34 days	42 days	Liquid	Micro-aerophilic <i>Streptococcus</i>	Débridement. Rib resection drainage. Secondary closure	Metallic foreign body, right lower lobe	Penicillin protection 48 hours. Thoracotomy with decortication, removal metallic foreign body from lung. Local penicillin. Penicillin 10 days postoperative	Complete primary cure. No complications.

TABLE I—(Cont.)  
SUMMARIZED DATA OF CASES

Case No.	Type of Injury	Time from Admission to Base Hospital to Operation	Time from Injury to Operation in Days	Type of Hemo-thorax	Etiologic Organism of Empyema	Previous Surgical Therapy	Pathology at Time of Definitive Therapy	Associated Thoracic Pathology
6.	SFVW pen. right	9 days	21 days	Clotted	<i>Proteolytic Clostridia</i>	Débridement. Thoracentesis. Secondary closure	Intrapleural metallic foreign body	
							Definitive Therapy	Result
							Penicillin protection 6 days. Thoracotomy with decortication, removal intrapleural metallic foreign body. Local penicillin.	Complete primary cure. No complications.
7.	SFVW pen. left	16 days	16 days	Liquid	<i>Nonhemolytic Streptococcus</i>	Débridement. Thoracentesis. Secondary closure	Metallic foreign body, left lower lobe. Bronchopleural fistulae	
							Penicillin 8 days postoperative. Penicillin protection 24 hours. Thoracotomy with decortication, removal metallic foreign body from lung. Closure bronchopleural fistulae. Local penicillin.	Complete primary cure. No complications.
8.	SFVW pen. right	6 days	10 days	Clotted	Definite pus. No organism identified	Débridement. Thoracentesis. Secondary closure	Metallic foreign body, right lower lobe	
							Penicillin 13 days postoperative. Penicillin protection 6 days. Thoracotomy with decortication, removal metallic foreign body from lung. Local penicillin.	Complete primary cure. No complications.
9.	SFVW pen. left	16 days	19 days	Clotted	<i>Proteolytic Clostridia</i>	Débridement. Thoracentesis. Secondary closure	Metallic foreign body, left upper lobe	
							Penicillin 6 days postoperative. Penicillin protection 24 hours. Thoracotomy with decortication, removal metallic foreign body from lung. Local penicillin.	Complete primary cure. No complications.
10.	SFVW pen. right	32 days	21 days	Clotted	Definite pus. No organism identified	Débridement. Thoracentesis. Early thoracotomy E. H. Secondary closure	Metallic foreign body, right lower lobe	
							Penicillin 12 days postoperative. Penicillin protection 24 hours. Thoracotomy with decortication, removal metallic foreign body from lung. Local penicillin.	Complete primary cure. No complications.
							Penicillin 7 days postoperative	

# LUNG DECORTICATION IN EMPYEMA

TABLE I—(Cont.)  
SUMMARIZED DATA OF CASES

Case No.	Type of Injury	Time from Admission to Base Hospital to Operation	Time from Injury to Operation in Days	Type of Hemo-thorax	Etiologic Organism of Empyema	Previous Surgical Therapy	Associated Thoracic Pathology at Time of Definitive Therapy	Definitive Therapy	Result
11.	GSW pen. left	3 days	11 days	Liquid	<i>Proteolytic Clostridia</i>	Early thoracotomy E. H. Secondary closure	None	Penicillin protection 48 hours. Thoracotomy with decortication. Local penicillin. Penicillin 14 days postoperative	Complete primary cure. No complications.
12.	Crush injury to chest	5 days	31 days	Clotted	<i>Proteolytic Clostridia, Hemolytic Staphylococcus aureus</i>	Thoracentesis	None	Penicillin protection 48 hours. Thoracotomy with decortication. Local penicillin. Penicillin 10 days postoperative	Complete primary cure. No complications.
13.	GSW perf. left	4 days	50 days	Clotted	<i>Hemolytic Staphylococcus aureus</i>	Débridement. Thoracentesis. Secondary closure	None	Penicillin protection 24 hours. Thoracotomy with decortication. Local penicillin. Penicillin 13 days postoperative	Small basal empyema requiring rib resection drainage.
14.	SFW pen. left	27 days	36 days	Clotted	<i>Hemolytic Staphylococcus aureus</i>	Early thoracotomy E. H.	Metallic foreign body embedded in posterior parietal pleura	Penicillin protection 48 hours. Thoracotomy with decortication. Local penicillin. Penicillin 8 days postoperative	Complete primary cure. No complications.
15.	SFW perf. right	20 days	28 days	Clotted	<i>Proteolytic Clostridia</i>	Débridement. Closure sucking wound. Thoracentesis. Secondary closure	None	Penicillin protection 48 hours. Thoracotomy with decortication. Local penicillin. Penicillin 8 days postoperative	Developed intra-abdominal abscess, associated with intra - abdominal foreign body. Primary cure of empyema.
16.	GSW pen. right	30 days	33 days	Clotted	<i>Proteolytic Clostridia</i>	Early thoracotomy E. H.	Intrapulmonary foreign body	Penicillin protection 24 hours. Thoracotomy with decortication. Local penicillin. Penicillin 7 days postoperative	Complete primary cure. No complications.

TABLE I—(Cont.)

SUMMARIZED DATA OF CASES.				Associated Thoracic Pathology at Time of Definitive Therapy		Definitive Therapy		Result
Case No.	Type of Injury	Time from Admission to Hospital to Operation	Time from Injury to Operation in Days	Type of Hemo-thorax	Etiologic Organism of Empyema	Previous Surgical Therapy	Definitive Therapy	
17.	SFW perf. right	55 days	64 days	Liquid	<i>Anaerobic Streptococcus hemolytic. Staphylococcus aureus</i>	Early thoracotomy E. H. Rib resection drainage for empyema	None	Complete primary c. re. No complications.
18.	SFW pen. right	18 days	20 days	Clotted	<i>B. proteus</i>	Débridement. Thoracentesis. Secondary closure. Reduction compound fracture right femur.	Local penicillin. Penicillin 15 days postoperative	Basal empyema requiring rib resection drainage. Empyema cleared after secondary drainage. Skeletal traction of femur probably influenced development of recurrent empyema.
19.	SFW perf. right	69 days	78 days	Liquid	<i>Anaerobic Streptococcus. Sporogones</i>	Application skeletal traction Early thoracotomy E. H. Anterior and posterior rib resection drainage for empyema	Multiple bronchopulmonary fistulae	Complete primary cure. No complications.
20.	SFW pen. left	17 days	42 days	Liquid	<i>Anaerobic Streptococcus</i>	Early thoracotomy E. H. Anterior and posterior rib resection drainage for empyema	Penicillin protection 48 hours Thoracotomy with decortication. Local penicillin. Penicillin 8 days postoperative	Complete primary cure. No complications.
21	SFW pen. right	10 days	14 days	Clotted	<i>Proteolytic Clostridia</i>	Early thoracotomy E. H. Anterior and posterior rib resection drainage for empyema Débridement. Thoracentesis Secondary closure	Multiple bronchopulmonary fistulae	Complete primary cure. No complications.
							Penicillin protection 72 hours. Thoracotomy with decortication. Local penicillin. Penicillin 13 days postoperative	
							Penicillin protection 5 days. Thoracotomy with decortication. Débridement closure of abscess. Local penicillin. Penicillin 14 days postoperative	Partial reopening of abscess. Recurrence of apical empyema requiring rib resection drainage. Recurrent empyema less than original process. Progress satisfactory.

# LUNG DECORTICATION IN EMPYEMA

TABLE I—(Cont.)

SUMMARIZED DATA OF CASES				Associated Thoracic Pathology at Time of Definitive Therapy		Definitive Therapy		Result	
Case No.	Type of Injury	Time from Admission to Hospital	Time from Injury to Operation	Type of Hemothorax	Etiologic Organism of Empyema	Previous Surgical Therapy	Retained in Definitive Therapy	Definitive Therapy	Result
22.	SFW pen. left	2 days	8 days	Clotted	<i>Protoclytic Clostridia</i>	Débridement. Thoracentesis. Secondary closure	Large metallic foreign body left upper lobe, with associated intrapulmonary abscess.	Penicillin protection 48 hours. Thoracotomy with decortication. Débridement closure of abscess. Local penicillin. Penicillin 10 days postoperative	Complete primary cure. No complications.
23.	SFW perf. multiple right trans-diaphragmatic	34 days	47 days	Liquid	<i>Hemolytic Staphylococcus aureus</i>	Early thoraco-abdominal E. H. Rib resection drainage for empyema	Multiple bronchopleural fistulae	Penicillin protection 17 days. Thoracotomy with decortication. Local penicillin. Penicillin 14 days postoperative	Basal empyema requiring rib resection drainage. Persistent anterior empyema cavity, may require future operative procedure.
24.	SFW pen. left	50 days	61 days	Liquid	<i>Anaerobic Streptococcus. Pseudomonas</i>	Early thoracotomy E. H. Rib resection drainage for empyema	Multiple bronchopleural fistulae	Penicillin protection 11 days. Thoracotomy with decortication. Local penicillin. Penicillin 16 days postoperative	Recurrent basal empyema requiring secondary rib resection drainage.
25.	Multiple perf. SFW severe	18 days	28 days	Clotted	<i>Protoclytic Clostridia Sporogones</i>	Rib resection drainage for empyema	Multiple bronchopleural fistulae. Multiple small intrapulmonary abscesses, with long connecting missile tracts	Penicillin 16 days postoperative. Penicillin protection 72 hours. Thoracotomy with decortication. Local penicillin. Penicillin 16 days postoperative	Basal empyema. Recurrence of bronchopleural fistulae. Bronchopneumonia contralateral side. Death after 8 weeks.

Explanation of abbreviations.  
SFW — shell fragment wound.  
GSW — gun shot wound.  
pen. — penetrating.  
perf. — perforating.  
E. H. — evacuation hospital.

current basal empyema following decortication, one (Case 18) occurred in a patient who had a fracture of the femur treated by traction throughout his postoperative thoracotomy course. The immobility of the patient thus engendered, we feel to have been contributory to the failure to obtain a primary cure in this case. It is to be stressed here that whenever long bone fractures occur in association with significant thoracic trauma the fracture should if possible be handled in such a fashion as to render the patient maneuverable. In our experience, a thoracic injury that is immobilized by skeletal traction for the treatment of a long bone fracture is very likely to do badly so far as the chest lesion is concerned. The second case with recurrent empyema in this group (Case 13) presents no reason, so far as we can see, for having failed to achieve a primary cure.

It is significant that of the six cases of recurrent empyema, four occurred in the second group; *viz.*, those with significant associated pulmonary pathology. These associated lesions were serious and complicated. A review of these lesions as summarized in Table I is interesting. Three cases of pulmonary abscess were encountered. All three were débrided and the remaining defects closed. In two of these (Cases 7 and 22), complete healing of the abscess with primary cure of the empyema was obtained. The third abscess (Case 21), much larger, reopened, and gave rise to a recurrent empyema. Despite this, we feel that these cases justify the validity of the method, and that they are striking evidences of the marked extension of surgical therapy that penicillin protection permits of in the eradication of sepsis.

In only one of the cases (Case 23) is there any likelihood that subsequent additional surgery will be necessary to effect a cure.

The consistently uneventful convalescent period and lack of any evidence of dissemination of infection is best appreciated perhaps by a study of the temperature and pulse records of the patients. For this purpose Figures 4, 5, and 6 are included. Figure 4 is the temperature and pulse chart of Case 8, Figure 5 is the temperature and pulse record of Case 20, and Figure 6 is that of Case 22. The absence of any marked reaction to operation is striking and was characteristic of the entire series. Even in the case that eventuated fatally (Case 25) the early postoperative course was favorable. Defervescence has been prompt in all cases. Where the empyema has recurred the temperature reaction was minimal.

The prompt and complete degree of pulmonary reëxpansion obtained in the 19 cases of primary cure is illustrated by the series of photographs of pre- and postoperative roentgenograms, which are included (Figs. 7, 8, 9, 10, 11, and 12). All of these were made within three weeks from the time of operation. They clearly demonstrate the early return to normal and the lack of any evidence of residual disease.

Not the least gratifying and impressive aspect of this series was the short time-interval necessary to effect a cure. Beside the weeks of daily dressings and tube changes required by the other methods these cases present a very

LUNG DECORTICATION IN EMPYEMA

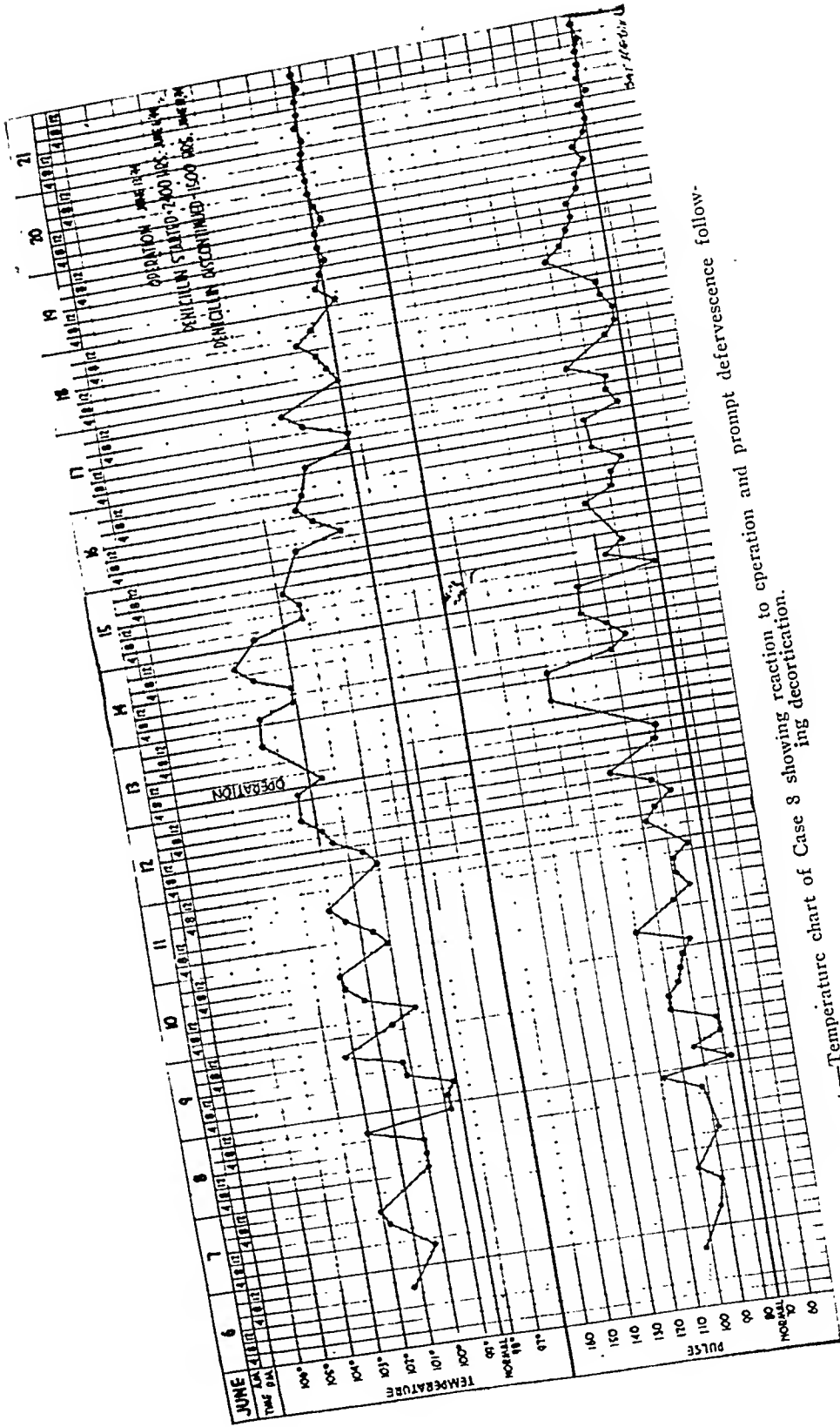


FIG. 4.—Temperature chart of Case 8 showing reaction to operation and prompt defervescence following decortication.



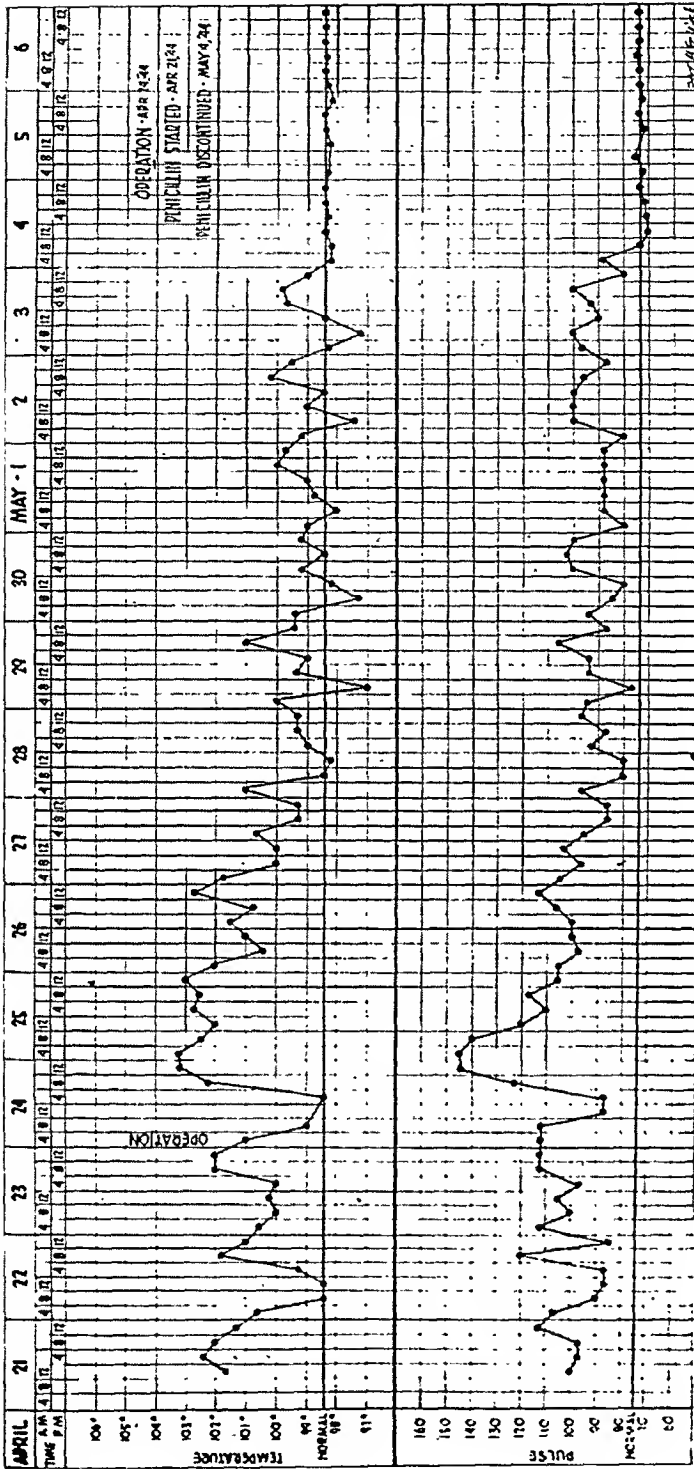


Fig. 5.—Temperature and pulse chart of Case 20 showing minimal reaction to operation and prompt return of pulse and temperature to normal.

# LUNG DECORTICATION IN EMPYEMA

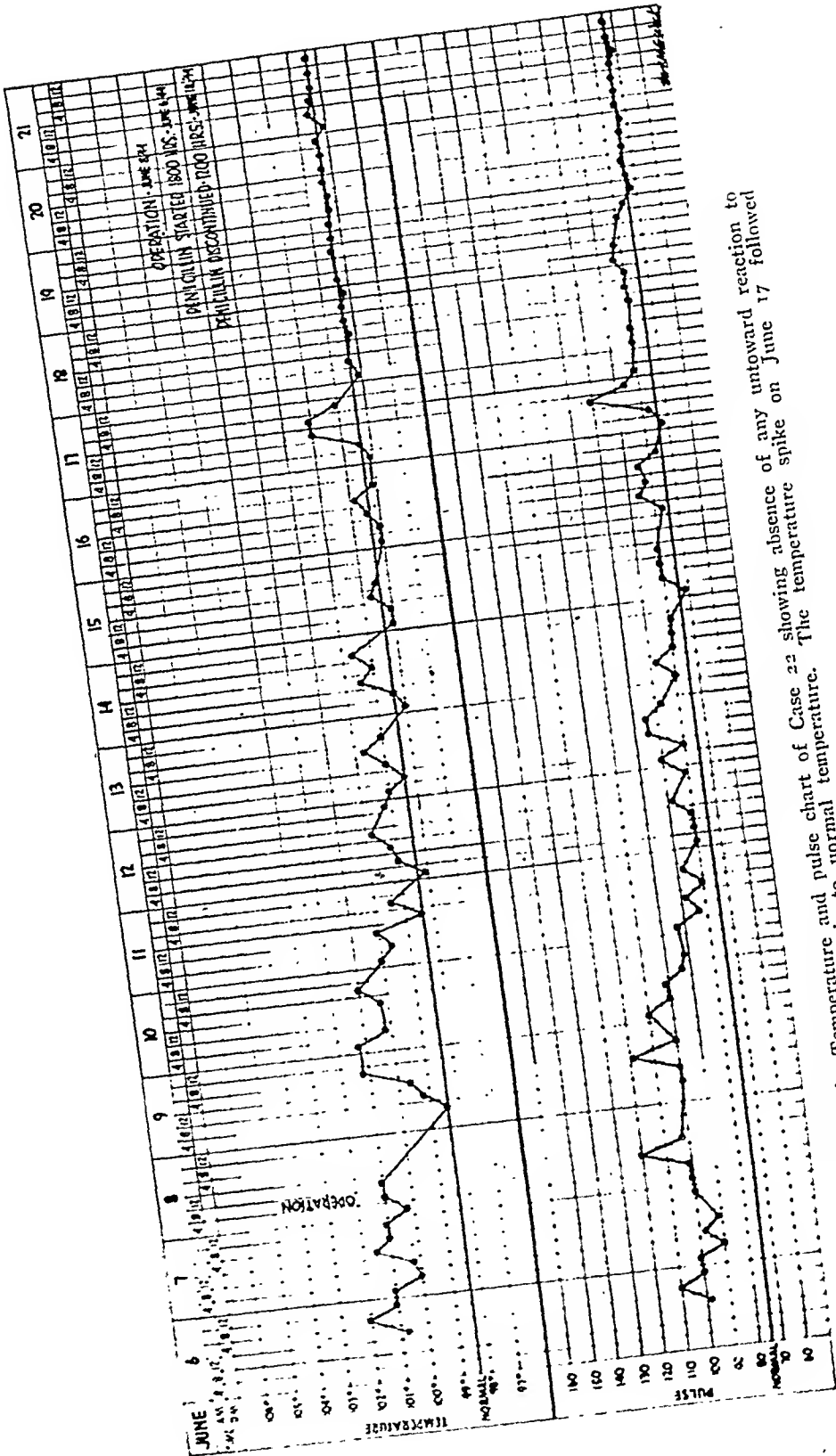


Fig. 6.—Temperature and pulse chart of Case 22 showing absence of any untoward reaction to operation and prompt lysis to normal temperature. The temperature spike on June 17 followed removal of the posterior intercostal tube.

FIG. 7

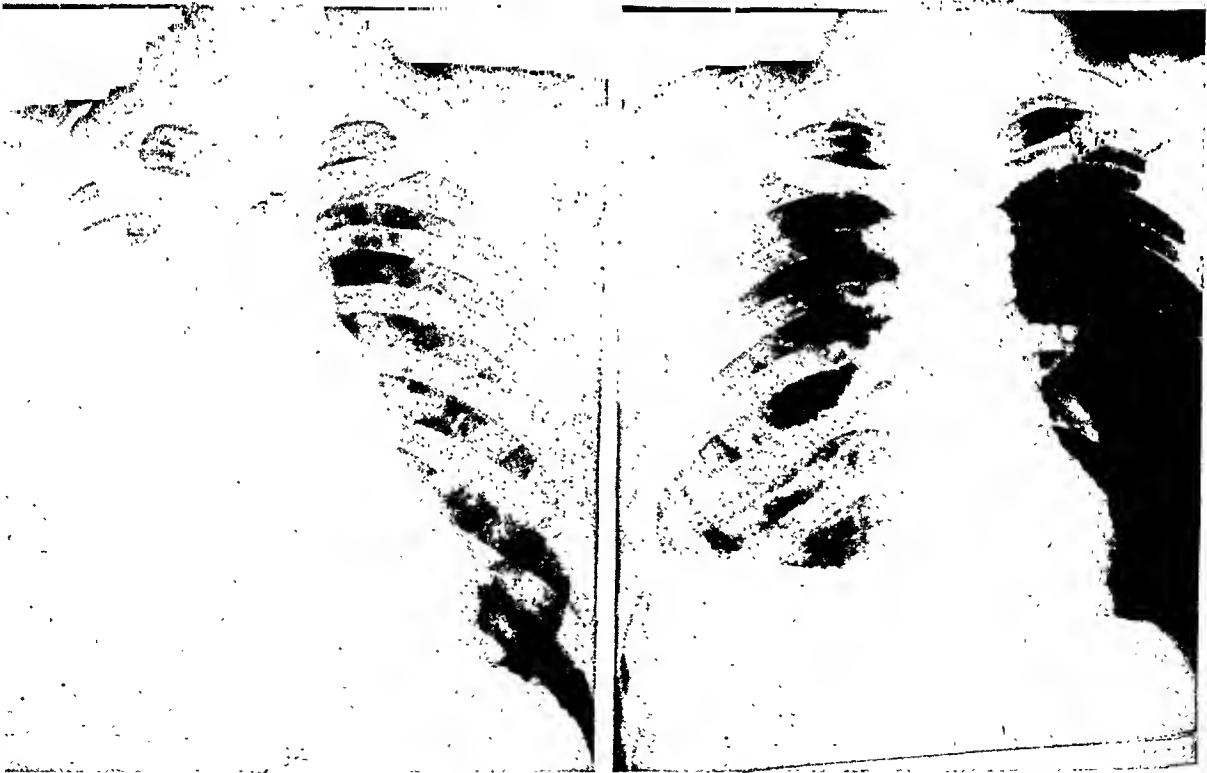
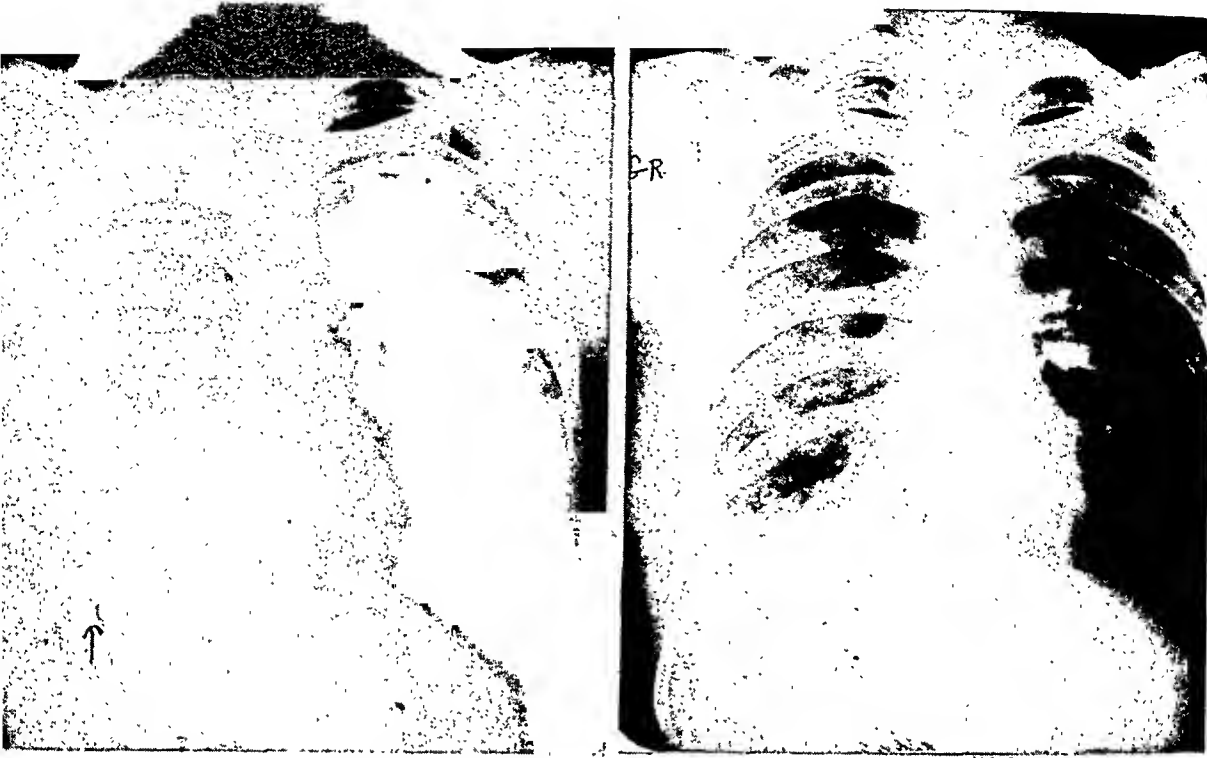


FIG. 8

FIG. 7.—Case 6: A. Roentgenogram of chest at the time of operation showing empyema of right pleural cavity with intrapleural foreign body.

B. Roentgenogram of chest three weeks after thoracotomy with decortication.

FIG. 8.—Case 8: A. Roentgenogram of chest showing organizing hemothorax, with empyema of right pleural cavity.

B. Roentgenogram showing chest two weeks after thoracotomy with decortication.

# LUNG DECORTICATION IN EMPYEMA

FIG. 9

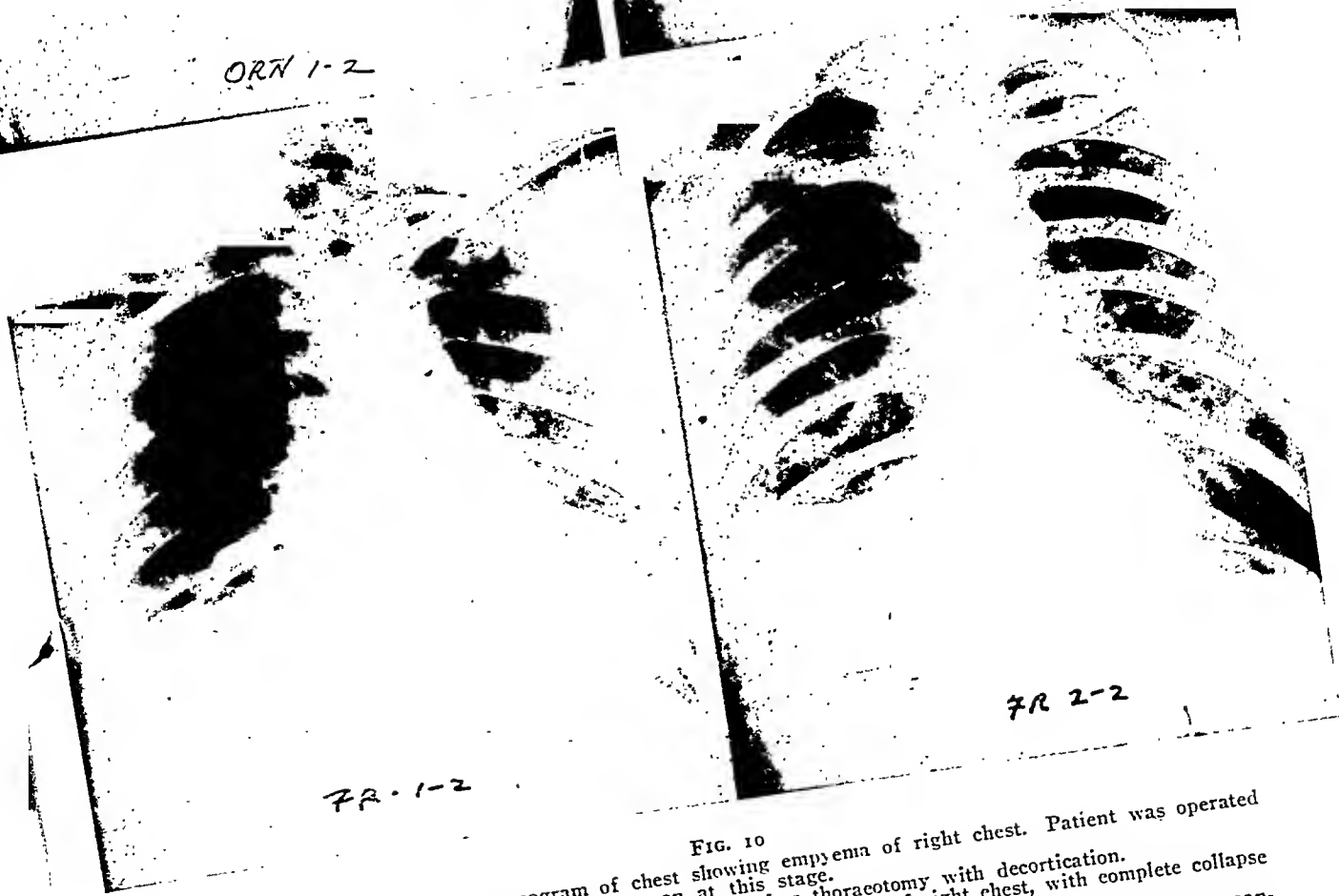
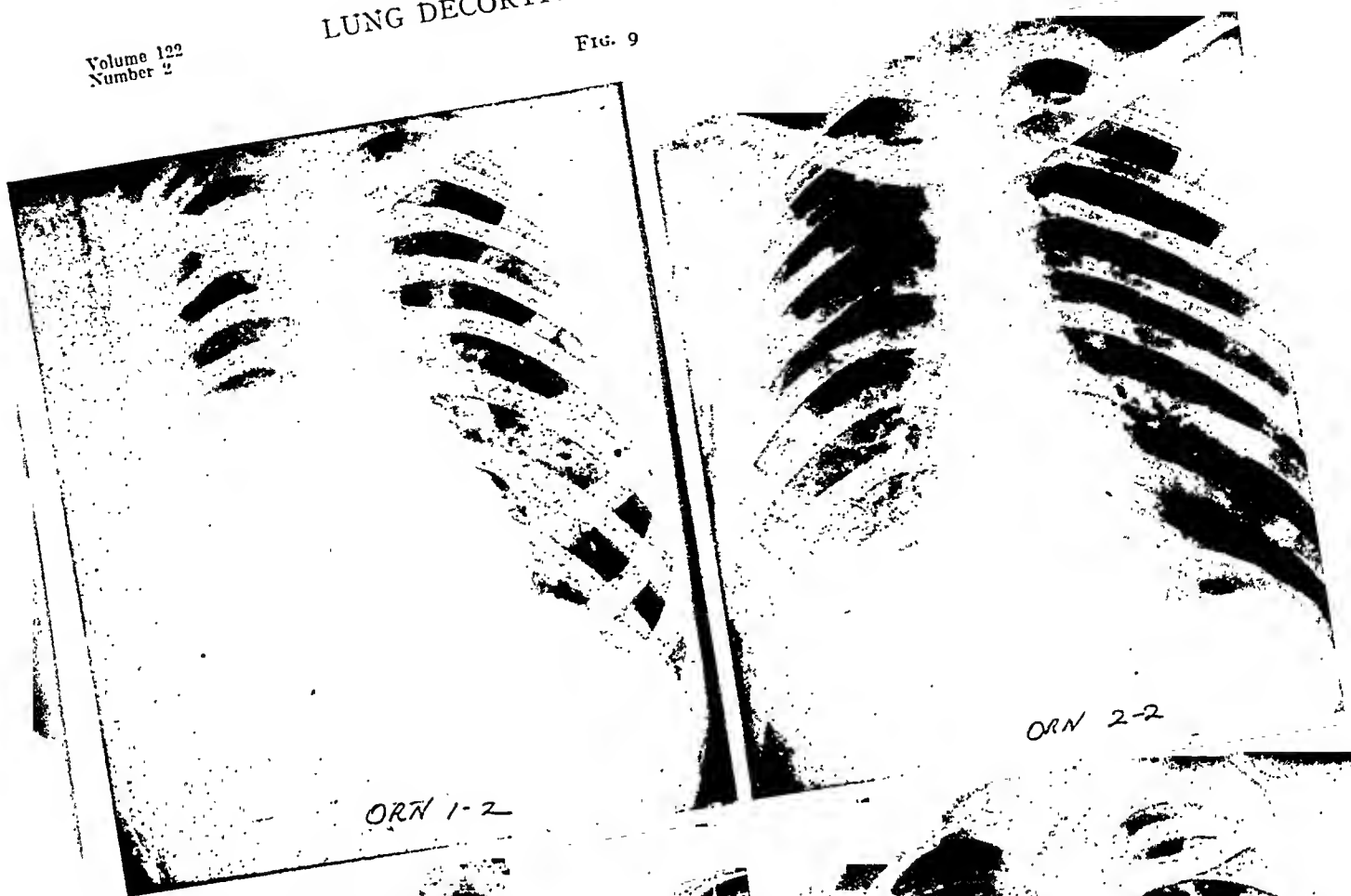


FIG. 10

FIG. 9.—Case 10: A. Roentgenogram of chest showing empyema of right chest. Patient was operated upon at this stage.  
B. Roentgenogram of chest two weeks after thoracotomy with decortication.  
FIG. 10.—Case 17: A. Roentgenogram of chest showing empyema of right chest, with complete collapse of right lung.  
B. Roentgenogram of chest three weeks after thoracotomy with decortication showing complete expansion and no empyema.

To those who would hold a brief for a more conservative approach to the therapy of posttraumatic empyema we emphasize the not insignificant mortality of the adequately drained empyema that "is doing well." Even the best managed case is unpredictable and the road from drainage to complete cure is beset with significant dangers. It requires but one metastatic brain abscess to emphasize this. Chronicity may eventuate at any stage. At best, the time elapsing before a cure is obtained is a matter of weeks. Uncertainty of outcome is inevitable so long as any vestige of an empyema cavity exists.

From a study of the 25 cases in this series we believe that early thoracotomy, with decortication, under penicillin protection is the method of choice in the therapy of total posttraumatic empyema. We feel that we can now approach the problem of posttraumatic empyema more rationally and more optimistically, certain of achieving a high percentage of primary cures, with early, complete functional restoration and a greatly lowered chronicity rate, with a minimum of risk to the patient.



#### SUMMARY AND CONCLUSIONS

1. The significance of the problem of posttraumatic empyema thoracis is presented and the basic pathology of the problem, which has been studied intensively, is discussed.

2. A concept of therapy has been rationalized on a basis of that pathology, and a plan of treatment is presented which is based on that concept. The treatment recommended consists of early pulmonary decortication under penicillin protection.

3. A series of 25 cases treated by this method are reviewed. Of this group, 19 (76 per cent) obtained a primary cure. Six developed recurrent basal empyemas. In only one is there any likelihood of a subsequent obliterative operative procedure being necessary to bring about a cure. The one death in the group occurred eight weeks after operation of continued sepsis, and is not classed as an operative death.

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Care of Office of the Surgeon General  
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# TRAUMATIC RIGHT DIAPHRAGMATIC HERNIA

CASE WITH DELAYED HERNIATION OF THE LIVER AND GALLBLADDER

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TRAUMATIC HERNIA rarely occurs through the right hemidiaphragm. In one large series its incidence is given as 5 per cent. In 857 cases of traumatic diaphragmatic hernia, the liver was found in the chest in but 14 cases.<sup>1</sup> The following case is reported because of several notable features: The herniation of the liver and gallbladder occurred through a rent in the right diaphragm late after the injury; the symptoms occasioned by the displaced organs were moderate, and the exact status of the herniated structures could be inferred from the roentgenologic examinations.

**Case Report.**—A 25-year-old bombardier received crushing injuries to the right lower chest, the right thigh, and the left forearm when his plane crashed in a faulty take-off. Upon admission to a Station Hospital he complained of pain in the right lower chest and right upper abdomen, stating that he felt as though all the wind were knocked out of his right lung. Roentgenograms demonstrated comminuted fractures of the middle third of the left radius and ulna, and an oblique fracture of the middle third of the right femur. A roentgenogram of the chest showed elevation of the right dome of the diaphragm to the level of the eighth intercostal space posteriorly; the heart and lungs were otherwise normal. He was observed for signs of a ruptured viscus or internal hemorrhage, but these did not materialize. Adhesive skin traction was applied to the right leg and the left forearm was placed in a plaster encasement. A course of sulfadiazine therapy was started immediately. For five or six days he complained of constant right chest pain, which gradually diminished. The pulse remained at about 110, and the respirations at about 25 per minute. He developed a slight productive cough for several days, but at no time did he expectorate blood. Ten days after admission he was transferred to this General Hospital.

**Physical Examination.**—The patient was a young male whose left forearm was in a plaster encasement, and whose right leg was in traction in a Thomas caliper splint. His temperature, pulse and respiratory were normal. Healing recent lacerations of the left elbow and right thigh were present. Although he complained of slight discomfort in the right lower chest on deep inspiration, the examination of the chest failed to show any abnormalities. The blood, urine and serologic tests were also normal. A roentgenogram of the chest showed slight elevation of the right diaphragm (Fig. 1).

After preliminary blood and plasma infusions an open reduction of the left forearm was undertaken. Skeletal traction was applied to the right femur. These procedures were performed under inhaled nitrous oxide-ether anesthesia, with intravenous sodium pentothal induction. No respiratory difficulty was encountered during the 100 minutes of anesthesia. The patient's convalescence was uneventful.

About three months later the patient began to complain of pain in the right lower chest, which was made worse by the ingestion of food. Peristaltic gurgles were heard high in the right axilla. A roentgenogram of the chest showed a large homogeneous density occupying the lower half of the right hemithorax (Fig. 2). Fluoroscopy in the erect and recumbent positions failed to show any change in the shape of the dense shadow, or any evidence of movement of the shadow with respiration. The films of

the abdomen and the chest showed gas-filled bowel, which was thought to be colon, high in the most lateral portion of the lower right axilla. The usually sharp lower margin of the liver could not be seen (Fig. 2). Examination of the colon by means of a barium enema verified the fact that the hepatic flexure was unusually high in position, and, again, failed to visualize the lower margin of the liver. It was postulated, therefore, that the liver had migrated into the lower portion of the right chest. In order to confirm this, cholecystography was done. This examination showed a markedly elongated narrow gallbladder, the fundus of which was directed upwards towards the right axilla (Fig. 3). Concentration and emptying after a fatty meal were good.

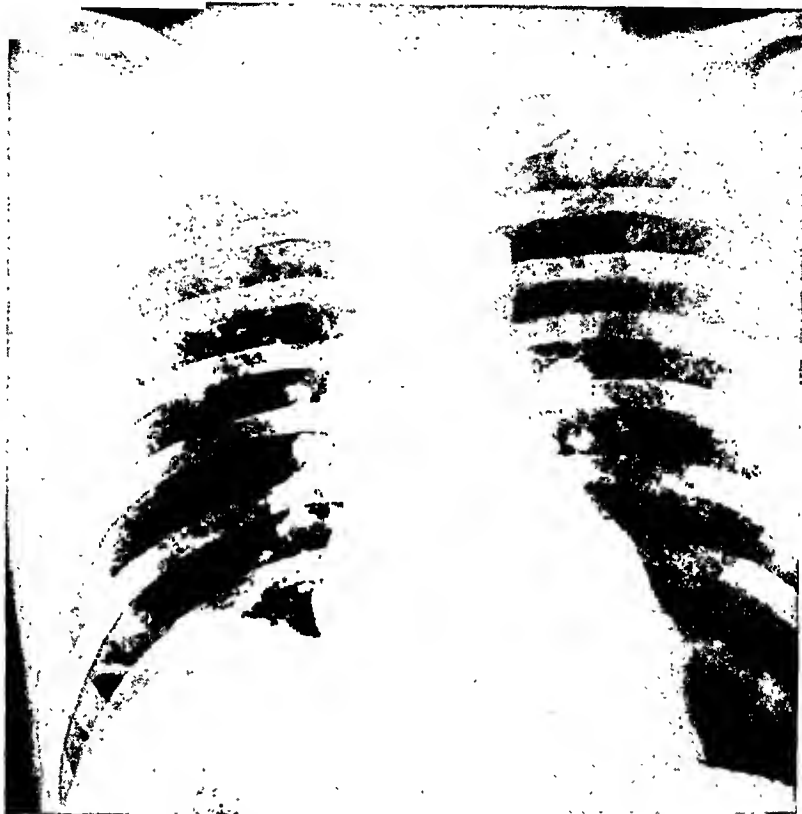


FIG. 1.—The right hemidiaphragm is somewhat elevated. This examination was made under bedside conditions on admission of the patient to this hospital.

At this time it appeared that the patient would need an open reduction of the femur, as well as a repair of the diaphragmatic hernia. It was decided to place the right leg in a long leg encasement, and to repair the hernia first. Vitamins and multiple blood and plasma infusions were given preoperatively. He was allowed up in a wheel chair, with improvement in appetite, bowel function, and general attitude.

A month after the onset of the new group of symptoms the right diaphragmatic hernia was repaired. With the patient lying on his left side, a long skin incision was made on the right side between the seventh and eighth ribs from the costochondral junction to the tubercle of the ribs. The seventh, eighth and ninth ribs were exposed in the posterior axillary line and two drill holes made in each rib about 2 cm. apart. These ribs were then cut transversely between the drill holes. The pleural cavity was opened between the seventh and eighth ribs and a self-retaining retractor inserted. This exposed the gallbladder and the under surface of the liver. This latter organ was lying in the thoracic cavity, completely upside down. The right hemidiaphragm was contracted and shrunken posteriorly and medially, and lay under the rotated liver. The

liver had turned  $180^{\circ}$  on its transverse axis, so that the inferior surface was lying superiorly. The gallbladder was stretched into a long thin tube-like structure which extended from the posterior superior portion of the chest down into the abdomen. The left lobe of the liver was displaced to the right of the round ligament and had rotated about  $120^{\circ}$ . The portal vein and the gastrohepatic omentum were stretched tensely, but not enough to impede the flow of blood or bile. A moderate amount of omentum and the tip of the hepatic flexure of the colon were above the diaphragm posteriorly.



FIG. 2.—A homogeneous shadow is seen in the lower half of the right side of the chest. Its upper border did not change with respiration or with change in posture. The heart is displaced to the right. Gas in the bowel, presumably colon, is present high in the abdomen (arrow). The usual lower margin of the liver cannot be seen. The patient is in a spica encasement.

There was a small amount of serous fluid posteriorly in the chest cavity. There were no adhesions, nor was there any evidence of previous hemorrhage or fracture of the liver. It was seen that the diaphragm was torn completely and cleanly from its attachment beginning near the sternum and extending entirely around the chest wall to the posterior axillary line on the right side. The free edge of the diaphragm and the site of its normal attachment were smooth and nicely healed. The peritoneal margin along the anterior abdominothoracic junction was clearly demarcated.

The liver was rotated into normal position with slight difficulty and simultaneously the omentum and colon were reduced into the abdominal cavity. The diaphragm was then pulled forward and laterally with ease, and its edges sutured to its previous attachments by multiple interrupted mattress sutures of No. 3 black silk. Interrupted sutures of No. 5 black silk were also used about 3 cm. apart. This effected an anatomic reposition of the diaphragm. The phrenic nerve was exposed above the diaphragm and crushed, resulting in an immediate cessation of diaphragmatic activity. During the



operation there was a marked mediastinal shift to the left, but respirations were controlled satisfactorily with positive pressure anesthesia. Stainless steel wire was then put through the holes in the ribs which had been severed, and anatomic position was restored. The pleura, except for the most mesial portion, was closed with interrupted sutures of "o" catgut chromic. The rest of the wound was closed in layers using the same suture material. Two loops of No. 5 chromic catgut were placed about the seventh and eighth ribs and tied to relieve tension on the soft tissue sutures. The mesial aspect of the wound was left open and interrupted sutures placed but not tied in all the layers. All fluid and blood was removed from the chest by suction, and the lung was expanded by positive pressure. The wound was then quickly closed by tying



FIG. 3.—Cholecystography shows a long tube-like gallbladder stretching to the level of the 5th rib posteriorly. This shadow changed in size after a fatty meal.

the previously placed sutures, thereby obtaining an air-tight closure. The skin was closed without drainage, using interrupted black silk sutures.

He was immediately started on penicillin systemically, 25,000 units every two hours. This was continued until the ninth postoperative day. His course was uneventful, the temperature, pulse and respiration becoming normal on the sixth day. On the third day postoperatively, 800 cc. of blood-tinged fluid were removed from the right pleural cavity by thoracentesis. The operative wound healed *per primam*. Three 500 cc. transfusions of blood were given during the first ten postoperative days. The patient had no further trouble with his chest.

A reexamination of the gallbladder after the operation showed it to concentrate very well. It had resumed its normal position and shape. The liver shadow was also seen to be in normal position (Fig. 4).

## TRAUMATIC DIAPHRAGMATIC HERNIA

DISCUSSION.—It is remarkable that the rotation of the liver did not produce obstruction of the portal or biliary system. It seems evident that the extensive diaphragmatic separation existed from the day of the accident, yet respiratory embarrassment and mediastinal shift did not occur. The liver itself probably plugged the gap and acted as part of the thoraco-abdominal septum. As time passed, the stretching of the attachments of the liver allowed it to prolapse into the chest. The contraction of the dia-



FIG. 4.—Postoperative cholecystography shows a gallbladder normal in size, shape, and position. The lower margin of the liver and the hepatic flexure of the colon, both now in normal position, can be seen.

phragm posteriorly and medially, exerting tension on the intact triangular ligament was probably a sufficient factor in initiating rotation of the liver. The constant action of the left hemidiaphragm transmitted through the abdominal contents completed the rotation of the liver and its upward displacement. Colon and omentum followed but due to the lack of inflammation these organs probably slid in and out of the chest with change in body position or physiologic activity. The absence of inflammatory reaction, of signs of previous hemorrhage, and the glistening smoothness of the peritoneal and pleural surfaces are unusual.

## SUMMARY

A case is described in which the right hemidiaphragm was detached through approximately 70 per cent of its costal origin. About four months after the original injury the liver herniated into the chest, rotating 180° on its long axis as it did so. Roentgenographic studies, particularly those of the gallbladder, suggested the disordered anatomy which was found at the operation. Restoration of the viscera to normal positions and repair of the hernia were accomplished.

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# THE VALUE OF ANTITOXIN IN THE PREVENTION AND TREATMENT OF MALIGNANT EDEMA AND GAS GANGRENE\*

## A REVIEW OF OBSERVATIONS

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THE HISTORY of malignant edema and gas gangrene may be divided into two periods, first, the prebacteriologic or purely clinical era, from 1607, when Hildanus first recorded a case<sup>1</sup>, to 1877, when Pasteur and Joubert<sup>2</sup> discovered the "*vibrio septique*," and, second, the bacteriologic era, from 1877 to the present.

Anyone interested in the prebacteriologic era of these anaerobic infections will find the work of Kellett<sup>1</sup>, Kirkland<sup>3</sup>, Martin de Bazas<sup>4</sup>, Maissoneuve<sup>5</sup>, Chassaingnac<sup>6</sup>, Macleod<sup>7</sup>, Pirogoff<sup>8</sup>, and Trifaud<sup>9</sup>, thoroughly worth while, but the present discussion relates exclusively to the problems of serum therapy. In order to appreciate this it is necessary briefly to discuss the complicated etiology of these diseases.

Malignant edema and gas gangrene are almost always the result of severe trauma coupled with excessive contamination with fecal micro-organisms present in the soil, upon clothing or other foreign objects carried deeply into the wounded tissues which are not removed promptly by surgery. Crushing injuries involving compound fractures of the limbs, gunshot wounds, bombing injuries, traumatic abortion, hypodermic injections and automobile and train accidents are the principal predisposing causes. Superficial injuries to the skin such as abrasions without crushing and even extensive burns rarely result in anaerobic infections. There are, thus, three main factors: (1) injury of a certain kind; (2) gross contamination with certain pathogenic bacteria; and (3) lack of adequate and prompt surgery. It is only when all three of these factors operate conjointly that malignant edema or gas gangrene result.

## SURGERY

Surgeons have recognized for many decades that compound fractures could be successfully treated by adherence to the principles of prompt and adequate débridement, immediate fixation, as for example, in plaster of paris and provision for free drainage. In 1884, when the rôle of bacterial infection was only vaguely appreciated, Dennis<sup>10</sup> recorded 144 cases without a single death from septic infection and 100 cases without a death from any cause.

More recently, Böhler<sup>11</sup>, after an amazing experience with 20,000 open traumatic wounds, including 253 compound fractures of the long bones and

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Dr. Frank L. Meleney of the Subcommittee on Surgical Infections was the Responsible Investigator.

more than 100 open tears of large joints, treated surgically, but without serum, lost only one patient from gas gangrene, while Trueta<sup>12, 13</sup>, had only one case of gas gangrene in over 1,000 compound fractures during the Spanish Revolution, relying mainly upon prompt, meticulous surgery, with immediate fixation in plaster.

These observations prove beyond question that if early débridement and adequate surgery are practiced, anaerobic infections are extremely rare. The real value of serotherapy in the treatment of wounds lies in the fact that it is so simple that it can often be administered very soon after a wound is received, making delayed surgery possible and effective, saving lives and limbs that would otherwise be lost. Essentially, the value of serotherapy is prophylactic, and to a much lesser degree, therapeutic.

Bacteriologically, the early conceptions of monospecific etiology based upon the work of Pasteur and Joubert<sup>2</sup> on "*vibron septicum*," and of Fraenkel<sup>14</sup> upon *Bacillus phlegmonis emphysematosae*, later shown<sup>15, 16</sup> to be identical with the *Bacillus aerogenes capsulatus* of Welch and Nuttall<sup>17</sup> and now properly called *Bacillus perfringens*<sup>18</sup>, gradually gave way in the early part of the century to the present conception that anaerobic wound infections, including malignant edema, gas gangrene and tetanus, are rarely pure infections but generally polymicrobial mixed infections in which two, three, or many species of bacteria, aerobic and anaerobic, pathogenic and saprophytic, putrefactive and fermentative, may participate. This change in point of view has been most clearly enunciated by Weinberg and Sequin<sup>19</sup>.\* At the close of World War I the principal primary cause of anaerobic wound infections other than tetanus were regarded as *Bacillus perfringens*, *Bacillus septicus*, *Bacillus novyi* and *Bacillus histolyticus*. To these has been added *Bacillus sordellii*<sup>20, 21, 22, 23</sup>. These five anaerobic bacilli are the principal specific causes of anaerobic wound infections other than tetanus, but their clinical manifestations are greatly modified by the various combinations in which they occur among themselves and with numerous aerobic and other anaerobic bacteria.\*

#### SEROTHERAPY

The first attempt at serotherapy in this connection was made by LeClainche<sup>24</sup>, in 1898, when he prepared an antimicrobial serum in an ass which would protect guinea-pigs and rabbits against several fatal doses of a culture of "*vibron septicum*," and would sometimes save their lives when given an hour after the culture was injected. In 1901, LeClainche and Morel<sup>25</sup> showed

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\*In this review the names used by various authors will be cited, but in case of doubt as to identity the following list of synonyms may be consulted:

*Bacillus septicus*, *vibron septicum*, *Clostridium septicum*, *Clostridium septicum*. *Bacillus tetani*. *Clostridium tetani*. *Bacillus perfringens*, *Bacillus aerogenes capsulatus*, *Bacillus phlegmonis emphysematosae*, *Bacillus welchii*, *Clostridium perfringens*, *Clostridium welchii*, *Fraenkel's gas bacillus*. *Bacillus novyi*, *Bacillus oedematis maligni* II, *Bacillus oedematis*, *Clostridium novyi*, *Clostridium oedematis*. *Bacillus histolyticus*, *Clostridium histolyticum*. *Bacillus sordellii*, *Bacillus oedematis sporogenes*, *Clostridium oedematoideus*, *Clostridium sordellii*.

that animals receiving a "serum-virus" mixture had no permanent immunity to "*vibrion septique*." No attempt seems to have been made immediately to apply such a serum in human cases of anaerobic cellulitis, which, at that time, was generally believed in France to be caused by the "*vibrion septique*."

Prior to World War I *B. perfringens* was vaguely supposed in France to be a possible cause of acute articular rheumatism, and a serum was prepared in horses by Thiroloix and Rosenthal<sup>26</sup> which in small quantities would protect guinea-pigs if given before, or simultaneously with, normally fatal doses of culture, and would even save them if given within three hours afterward in larger doses. Rosenthal<sup>27</sup> used this serum in proving the identity of *B. perfringens* with Achalme's anaerobic bacillus of rheumatism and later suggested its therapeutic application<sup>28</sup>, but we have no record of any observations in this direction. Neither is there any indication in the literature that the relation of *B. perfringens* to gas gangrene was appreciated at all in France prior to the outbreak of World War I.

In America, on the contrary, Welch and Nuttal's "gas bacillus" was widely accepted as the essential cause of gas gangrene, but the common method of treatment, as summarized by Cramp<sup>29</sup>, in 1912, was one of conservative surgery under spinal anesthesia, amputation when indicated, leaving wounds wide open, frequent inspections and irrigations with H<sub>2</sub>O<sub>2</sub>.

Shortly after World War I began it was realized that gas gangrene would be a major problem, and Weinberg, who was assigned to the study of the English wounded, soon recognized the importance of *B. perfringens* and of mixed infections as well as the infrequency of "*vibrion septique*." Almost at once he began to experiment first with vaccines<sup>30</sup>, and soon after with anti-serums against *B. perfringens*<sup>31</sup>. In 1915, after studying about 80 cases, a soldier treated with antiperfringens serum died from a "*vibrion septique*" septicemia. Weinberg's determination to prepare a bivalent serum against gas gangrene dates from this incident<sup>32</sup>.

About the same time Raphael and Frasey<sup>33</sup> reported a successful antitoxin against "*vibrion septique*" and, in 1916, a bivalent serum was made by Le Clainche and Valee<sup>34</sup> against *B. perfringens* and "*vibrion septique*."

In 1916, Weinberg<sup>35, 36</sup> was still talking about the use of his "omnivalent iodized autovaccine" but he was also hopeful of antitoxic and antimicrobial serums against *B. perfringens*, "*vibrion septique*" and *B. oedematiens*. In 1917, Weinberg and Sequin<sup>37</sup> produced a successful serum against "*vibrion septique*," and a little later *B. perfringens* and *B. oedematiens* as well<sup>38</sup>. With this trivalent serum they reported 19 cures in 30 cases, whereas, in a group of 66 cases treated without serum there were 35 deaths. Further tests were made of Weinberg and Sequin's serum by Vaucher<sup>39</sup>, and of both this and LeClainche and Valee's serum by Ivens<sup>40</sup> on larger numbers of cases, with encouraging but inconclusive results. Individual cases, such as that of Delbet<sup>41</sup>, often responded brilliantly, and LeClainche<sup>42</sup> reported 31 out of 40 cases as cured by his serum. Duval and Vaucher<sup>43</sup> injected 50 men from 5 to 18 hours after they were wounded, with either *B. perfringens* and *B. oede-*

*matiens* antiserum, or *B. perfringens* and "*vibrio septique*" antiserum or a mixture of these, all prepared by Weinberg and Sequin. Twenty-five of these patients died within 24 hours on account of their severe wounds, but without gas gangrene; 24 lived under observation for periods of 8 to 28 days without developing gas gangrene. These observers concluded that (1) prompt serotherapy was fully justified; (2) it could not be regarded as a substitute but as an important adjuvant of surgery; and (3) it had definite therapeutic value also. Subsequently these authors<sup>44</sup> reported the survival of all but two of 74 severely wounded men given these serums within 48 hours, without gas gangrene and without amputations. As a result of this report the Societe de Chirurgie de Paris voted to adopt the use of these serums in all wounded men likely to develop gas gangrene. A little later, Duval and Vaucher<sup>45</sup> reported on the preventive inoculation of 449 wounded men of whom 55 died from trauma without gas gangrene. Thirteen men should not have been injected. There were only 18 cases (4.7 per cent) of gas gangrene among 381 which might have occurred. Of these 18 cases, 10 died while 8 recovered after amputation of damaged limbs. In control groups not treated the number of cases ran 15 to 18 per cent.

Ivens<sup>46</sup> reported essentially similar favorable observations on 376 cases of wounds of which 236 had fractures, treated either with Weinberg's serum or that of LeClainche and Vallee.

Mairess and Regnier<sup>47</sup> treated 297 wounded men with evidence of anaerobic bacteria in their wounds, with serums from the Institute Pasteur. Of these, 25 developed gangrene and required secondary serotherapy. Only five died of gas gangrene. The clinical impressions were regarded as very favorable.

Vincent and Stodel<sup>48</sup> observed that under the influence of serum the general and local symptoms mended rapidly, the pulse and fever were lowered, the urinary secretion increased, and the wounded men's spirits revived. Of 81 treated, 12 died but only 8 died from gas gangrene.

It should be noted here that all of the above observers insisted upon the prompt use of the serum in fairly large amounts, which could not be clearly defined because of lack of any real method of standardization. None decried the absolute necessity of surgery and none regarded serotherapy as any substitute for surgery.

In Germany, a "Gasbrandserum gegen der Fraenkel'schen Gasbacillus" was prepared by Fraenkel and Zeissler<sup>47</sup> of which doses of 0.2 cc. intraperitoneally would protect guinea-pigs against many fatal doses of culture given intramuscularly four hours later, while polyvalent antigas gangrene serums of somewhat uncertain composition were prepared by Aschoff<sup>50</sup>, and by Kolle. Sachs and George<sup>51</sup>, which prevented experimental infections in guinea-pigs, and saved about 44 per cent of wounded soldiers threatened with gas gangrene.

It seems clear that the trivalent serum made by Weinberg and Sequin, in 1916 and 1917, contained antitoxins for *B. oedematiens* (*B. novyi*) and "*vibrio septique*" (*B. septicus*), but there was no evidence then for anything but

antibacterial antibodies against *B. perfringens*. Bull and Pritchett<sup>52</sup>, in 1917, first demonstrated the production of a true though weak, exotoxin by "*Bacillus welchii*" (*B. perfringens*), and prepared an antitoxin in rabbits which would neutralize its action in pigeons. Later, Bull<sup>53</sup> prepared a serum from a horse which arrested and controlled established infections and conferred passive immunity durable for two weeks in guinea-pigs. A few cases of gas gangrene in man were treated "in which the efficiency of the antitoxin was unmistakable<sup>54</sup>."

Wilson<sup>55</sup>, analysing 76 cases of gas gangrene occurring at a Base Hospital, felt after the war that the case for serum treatment had not been proven clinically, but Van Beuren<sup>56</sup> summarizing the best practice at the close of the war, and giving full data on numbers of wounded and incidence of gas gangrene in World War I, was favorable to the use of serum as an important adjunct to surgery. Equally favorable were the reports of Haniquet<sup>57</sup>, Sacquepee<sup>58</sup> and Vincent<sup>59, 60</sup>. Sacquepee pointed out that among 191 cases of gas gangrene treated with trivalent serum there were 160 cures and only 25 deaths, a mortality of about 13 per cent as compared with 75 per cent in untreated cases in the same region. Among 319 cases of severe wounds treated preventively only four cases of gas gangrene occurred.

One of the best reports on the treatment of gas gangrene, as it was known at the close of the war, was that of Ireland, *et al*<sup>61</sup>. This was also favorable to the use of gas gangrene serum.

#### USE OF GAS GANGRENE SERUM IN CIVIL PRACTICE

After the war it was several years before reports of the use of gas gangrene serum in civil injuries began to appear. Many of these reports are notable for their obvious lack of adequate bacteriologic data. In many instances there is nothing but the bare statement that "the gas bacillus" was demonstrated microscopically, and in some cases by culture. It is obvious that isolation in pure culture was rarely attempted, so that the problem of actual specific identity of either "the gas bacillus" and of the commonly associated other bacteria, both aerobic and anaerobic, is left untouched in these reports. Many are also reports of one or a few cases insusceptible even to the crudest statistical analysis; there is no point in citing these. Furthermore, the antibody content of the serums used was rarely described accurately; in fact the antibody content of commercial gas gangrene serums has been a subject of frequent discussion and change for many years, and serums made by different companies often differed not only qualitatively in the specific antibodies represented but quantitatively as well. It is only in the last few years that official international standards have been available for the group of antitoxins represented in the polyvalent gas gangrene serum. The present writer<sup>62</sup> has only recently pointed out how unsatisfactorily and confusing the present standards are. The international units of antitoxin are so defined that no two represent the same protective power; the unit of *Bacillus sordellii* antitoxin is about 50 times as strong as that of *Bacillus perfringens* while that of *Bacillus novyi* is



about 100 times as strong. Under the circumstances, the data available in the literature do not seem suitable for comparative analysis but the over-all impression is favorable to the use of serum as an adjunct to surgery.

Among those whose experience with series of cases published during the decade 1927 to 1937 entitles them to express opinions favorable to the use of serum were Tenopyr<sup>63</sup>, Weintrob and Messeloff<sup>64</sup>, Boland<sup>65</sup>, Larson and Pulford<sup>66</sup>, Milch<sup>67</sup>, King<sup>68</sup>, Stone<sup>69</sup>, Warthen<sup>70</sup>, Ghormley<sup>71</sup>, Eliot and Easton<sup>72</sup>, Velicanov<sup>73</sup>, Davis and Hanelin<sup>74</sup>, Collier<sup>75</sup>, Bates<sup>76</sup>, Veal<sup>77</sup>, and Eliason, Erb and Gilbert<sup>78</sup>.

Illustrating a general point of view, in 1937, Bates reported 16 cases treated surgically without serum, of whom eight (50 per cent) died, while of 16 cases treated with serum as an adjunct to surgery, only three (18.7 per cent) died, and Veal recorded 13 deaths (48.1 per cent) out of 27 cases at Charity Hospital, in New Orleans, treated therapeutically but not prophylactically with serum, as against four (80 per cent) out of five without serum, two (7.4 per cent) out of 27 treated prophylactically, and ten (20.4 per cent) out of 49 treated both prophylactically and therapeutically. Eliason, Erb and Gilbert concluded that, "the value of serotherapy seems to be well established."

#### CHEMOTHERAPY

##### EXPERIMENTS UPON ANIMALS

Although many different antiseptics have been tried in the treatment of gangrenous wounds throughout the years, the first serious attempt to apply the principles of modern chemotherapy was made in 1937 when Domagk<sup>79</sup> stated that infections with "*C. welchii*" and "*C. septicum*" responded well to sulfanilamide compounds (uleron) with a substituted sulfamino group. However, Long and Bliss<sup>80, 81</sup> obtained poor results in mice inoculated with whole toxic cultures but with cultures centrifugalized and resuspended in glucose broth and inoculated intraperitoneally, which killed only 90 per cent of the controls, they were able to save from 44 to 100 per cent of the mice treated within an hour with 28 to 96 mg. of sulfanilamide, while none of those receiving 20 mg. survived. They interpreted this action of sulfanilamide as purely bacteriostatic.

Spray<sup>82</sup> found that the bacteriostatic action of prontosil-soluble, sulfanilamide and disulfanilamide increased in the order named against *B. tetani*, *B. novyi*, *B. septicus* and *B. histolyticus*, but that *B. welchii* and certain putrefactive anaerobes were scarcely affected *in vitro* under his experimental conditions.

Osgood and Powell<sup>83</sup>, in 1938, showed that sulfanilamide did not inactivate the hemotoxins of *B. perfringens* or "*Cl. oedematis maligni*" (*B. septicus*?) *in vitro*, whereas, Carpenter and Barbour<sup>84</sup> found that sulfanilamide inactivated the toxins of *B. perfringens*, and other bacteria, *in vitro* and *in vivo* (mice) as well. These investigators were able with sulfanilamide to save 90 per cent of their mice injected intramuscularly with the toxin of *B. perfringens*, while only 12 per cent of the controls, not treated, survived.

Kendrick<sup>85</sup>, on the contrary, was unable to demonstrate any significant therapeutic effect of neoprontosil, sulfanilamide or sulfapyridine in guinea-pigs inoculated with whole cultures of *B. perfringens* and found *B. perfringens* antitoxin much more effective.

In 1940, articles began to appear suggesting the possibility of synergic action when drugs were administered in conjunction with antitoxic serum. One of the first of these was that by Henderson and Gorer<sup>86</sup>. These investigators found that sulfapyridine was an efficient prophylactic and therapeutic agent against *vibrion septicus* (*B. septicus*) inoculated intradermally into mice, but was unreliable when the mice were inoculated intramuscularly. *C1. welchii*, Type-A, was susceptible to sulfapyridine only upon prophylactic inoculation of mice infected by the intradermal route. Sulfanilamide was less effective than sulfapyridine against both organisms, and there was no evidence that sulfapyridine given *per os* neutralized the toxin of either organism. It was found possible to control infections with *vibrion septicus* by either antitoxin or antibacterial serum at a time when sulfapyridine was of little use, but the combined use of serum and sulfapyridine for both infections produced a noticeable synergic effect. These results were essentially confirmed by Stephenson and Ross<sup>87</sup> for *C1. welchii*, Type-A and "*C. septicus* (*sic*)", but neither sulfanilamide nor sulfapyridine had any effect on "*C1. oedematiens*." In Australia, Singer<sup>88, 89</sup> found that the use of antitoxic serums in mice infected with *C. welchii* or *C. septicum* made it possible to reduce greatly the effective dose of sulfanilamide but sulfanilamide was completely inactive against *C. oedematiens* and *Bacillus histolyticus*.

Gordon and McLeod<sup>90</sup> concluded from their experiments in mice and guinea-pigs, and other data, that the sulfonamide drugs were likely to have only a limited value in prophylaxis against gas gangrene, and that antiserums were much more effective in prophylaxis than drugs. Hawking<sup>91</sup> favored the combined use of sulfonamide drugs and antitoxin, and Reed and Orr<sup>92</sup> stated that "there is nothing to contraindicate the combination of these two forms of therapy."

#### OBSERVATIONS UPON PATIENTS

During the period of seven years in which the above experiments were recorded, many observations were also made upon accidentally infected wounds in human subjects. Lacking adequate controls, even bacteriologic analysis in many cases, and sometimes colored by wishful thinking, these are exceedingly difficult to evaluate. For example, Bohlman<sup>93</sup>, who stated that the use of gas gangrene antitoxin had been disappointing in his hands, reported three cases as successfully treated with sulfanilamide. But each received 10,000 units of serum and there was apparently no examination to determine the species of bacteria present. Yet these cases have been frequently cited as proving the value of sulfanilamide in gas gangrene.

Kennedy<sup>94</sup>, who condemned amputation as a means of saving life in gas gangrene, presented a case of gas gangrene in a boy following a shotgun wound treated with gas gangrene antitoxin, tetanus antitoxin, transfusion,

amputation (!) roentgen ray and sulfanilamide. There was no record of microscopic or cultural examination. Recovery was attributed to sulfanilamide!

Mellon, Gross and Cooper<sup>95</sup> described a case of "gas gangrene" following catheterization of an elderly man with chronic prostatitis and diabetes. *B. coli* was the only organism demonstrated. Treatment with gas gangrene serum gave only temporary relief, and the patient died after receiving large doses of sulfanilamide. This record is obviously unfair to both methods of treatment.

Of more value than any of these were Sadusk and Manahan's<sup>96</sup> two cases of postabortal septicemia, with positive cultures of *B. perfringens*, apparently saved by the oral administration of sulfanilamide. No serum was used in these cases.

Cruickshank<sup>97</sup>, in an admirable discussion of the whole problem of infected wounds, and recognizing the doubt in the minds of some surgeons regarding the value of antitoxin, still favored the combination of sero- and chemotherapy. Ogilvie<sup>98</sup>, likewise, favored the combined prophylaxis and therapy, and emphasized that "it is particularly important that serum should be given to those cases likely to develop gas gangrene, that is, men with lacerated wounds involving muscle who are unlikely to undergo débridement within the safe period." Lockwood<sup>99</sup>, also, in a general discussion of sulfanilamide in surgical infections, concluded that "for the present it would seem that our chief reliance should be on prevention of gas gangrene by débridement of susceptible wounds and administration of prophylactic antitoxin." Warthen<sup>100</sup>, on the other hand, in a summary of 71 cases of gas gangrene presented with incomplete bacteriologic data, was unable to find any single agent or drug specific in treatment, and stated that "perfringens antitoxin has been disappointing both prophylactically and therapeutically." Compare this with MacFarlane's<sup>101</sup> summary of 139 cases, in which "the fatality rate was significantly lower among patients who received antitoxin." MacFarlane emphasized "the necessity for the early and combined use of surgery, effective chemotherapy and antitoxin in the treatment of gas gangrene." The same general point of view was expressed by the British War Wound Committee<sup>102</sup>, by MacLennan<sup>103, 104</sup> after an extensive experience covering four years in North Africa, and by Porter<sup>105</sup> in the South Pacific.

#### DISCUSSION AND SUMMARY

It seems clear from this study that whenever it is possible, as for example, in most sporadic civilian wounds, to undertake adequate surgery promptly, anaerobic infections may be prevented by this means alone, without recourse to the administration of either prophylactic serums or prophylactic drugs. However, the prophylactic use of either serums or drugs, or both, together may serve a valuable purpose in making both early and delayed surgery more secure, or in permitting primary closure of a wound which would otherwise be left open, and many surgeons now prefer to use both these adjuncts. But the use of serums or drugs can never be regarded as a substitute for adequate surgery.

As a bacteriologist, the writer is impressed with the general lack of careful, detailed bacteriology in most of the cases of gas gangrene that have been recorded. It seems important that more bacteriologists be trained in the techniques of isolating and identifying the bacteria, particularly the anaerobic bacteria, which occur in the mixed infections of malignant edema and gas gangrene. It seems obvious, that too many of those who report these cases feel that they have done their duty when they record the presence of "the gas bacillus." It is rare, indeed, to see a detailed report of the various aerobic and anaerobic species which are generally present.

The treatment of infected wounds under catastrophic conditions, as in war, earthquakes and train accidents, must, necessarily, be based upon the assumption that prompt surgery is generally impossible. Under these conditions the injection of polyvalent, preferably pentavalent, gas gangrene antitoxin and tetanus antitoxin assumes a major prophylactic rôle, making possible and effective delayed surgery to save lives and limbs. It is necessary, of course, to guard against anaphylactic shock in asthmatics and others sensitive to horse serum.

Sulfonamide drugs and penicillin may serve a similar prophylactic rôle. Porter<sup>105</sup> was quite convinced that the value of application of sulfanilamide in war wounds and of sulfathiazole by mouth was fully proved. Key<sup>106</sup> believed that sulfonamide powders should be implanted in all clean operative wounds in both civilian and military hospitals, but Meleney's<sup>107</sup> observations on civilian wounds cast serious doubt upon this prevalent practice. Meleney found from his analysis of 1,500 civilians with contaminated accidental wounds, compound fractures and burns, that while the use of the sulfonamides minimized the general spread of infections and cut down the incidence of septicemia and death, there was no evidence that they lessened the incidence of local infection. One can only point out that the conditions under which most civilian wounds are treated are so different from those under which war wounds are treated that it is scarcely possible to reason from one to the other. The final judgment in reference to the prophylactic value of both antitoxic serums and drugs, applied either locally or systemically to war wounds, would seem to this writer best decided by similar statistical studies upon war wounds.

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# THE IMMEDIATE AND LATE TREATMENT OF AN ARTERIOVENOUS FISTULA\*

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ONE MAY PREDICT with confidence that many abnormal communications between the larger vessels will be established by wounds sustained in this war and that they will provide, unless early and successful treatment is available, some very interesting clinical phenomena and difficult problems both for the internist and the surgeon. In 1937, Basil Price<sup>1</sup> recorded his experiences with five cases from the last war whose arterial-venous wounds were sustained 20 years previously. In three instances operations had been considered impossible because of advanced cardiac disability, and two patients had died, one from a ruptured varicose vein distal to the fistula, and one from cardiac failure. The third patient will undoubtedly die of cardiac decompensation unless an operation for the elimination of the fistula can be performed successfully, a possibility which should still be considered despite the cardiac disability. Even advanced cardiac failure with generalized edema, ascites and hydrothorax has been cured completely by the elimination of an arteriovenous fistula.<sup>2</sup> In Price's two remaining cases incomplete operations have improved but have not cured the lesions. Increasing cardiac disability directly due to the fistulae may be expected as time elapses, and reoperation should also be considered for them, if at all possible.

The lesion provides one of the most fascinating examples of pathologic physiology:<sup>3</sup> the introduction of a fistula into the circulation superimposes upon the normal circulatory bed a second, or fistulous, circuit which is in reality *parasitic* upon the first. The normal circulation consists of the heart, arterial bed, capillary bed, and venous bed. The fistulous circuit consists of the heart, the artery between the heart and the fistula, the fistula, and the vein between the fistula and the heart. Common to both systems, are obviously, the heart, the artery to the fistula, and the vein from the fistula to the heart (Fig. 1). Each system requires a certain volume of blood to satisfy its needs, the need of the fistulous circuit depending upon the amount of blood which the fistula is capable of transmitting. Experimentally, and clinically, when the parasitic circulation attracts to it the greater volume of blood, the animal or patient dies.

The effect of the diversion of blood from the normal arterial bed into the parasitic circuit is many fold: There occurs (1) a lowering of blood pressure comparable with that accompanying massive external bleeding from a large vessel; (2) an accelerated pulse rate as a compensation for the lowered blood pressure, and as a response to the increased venous filling of the heart;

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\*The opinions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

(3) a great increase in cardiac output indicating a greatly increased volume flow of blood through the fistulous circuit; (4) a temporary or fleeting reduction in the size of the heart, and of the artery proximal to the fistula, due to a redistribution of blood from the central arterial to the peripheral venous vascular bed.

The loss of blood from the normal circulation with its concomitant fall in blood pressure is at first rectified, as in any bleeding to the outside, by the accretion of fluid from the tissues, and by cells and fluid from such organs as the spleen and liver. This restoration of the circulating blood to a volume adequate to meet the needs of both the normal and parasitic circulations results in (1) a recovery of systolic blood pressure to normal, but a permanent lowering of diastolic pressure due to a permanently decreased peripheral resistance at the site of the fistula; (2) a return of the pulse rate to a more normal rate, although at times the acceleration may persist; (3) an increased total blood volume; and (4) an increase in the volume of blood flowing through that part of the circulatory system common to both the normal and parasitic circuits.

This increased volume, or bulk, of blood flowing through the fistulous circuit including the four chambers of the heart, distends and dilates it to a greater or less degree depending on the volume flow through the fistula. Experimentally, it has been proven that the entire part of the circulatory bed through which the short-circuited blood passes becomes dilated.<sup>4</sup>

The interdependence of the size of the normally functioning heart and the volume flow of blood through it has been demonstrated also under other conditions. In massive bleeding the removal of 500 cc. of blood from the circulation of a 12-kilogram dog will reduce the heart to one-half its normal size. In shock the size of the heart is greatly reduced due to redistribution of the normal blood volume. In histamine shock the peripheral vasodilatation causes the blood to leave the central circulatory bed and to accumulate in the peripheral vascular bed. In traumatic shock, the blood leaves the central bed, and accumulates in the traumatized area. Similarly, on opening a fistula the blood leaves the normal arterial bed, and fills the capacious, easily distensible venous bed, and the heart temporarily decreases in size. Experimentally, however, this initial decrease in the size of the heart is very fleeting, lasting perhaps a few hours to a few days, after which there occurs a gradual dilatation of the heart and of the vessels leading to and from the fistula, in some instances to an enormous size.

This gradual dilatation of the fistulous circuit which often continues over a period of years, is explained as follows: The peripheral resistance at the site of the fistula in circuit PN (Fig. 1) is obviously less than the peripheral resistance in the arteriolar and capillary bed of circuit N. Flowing blood, like flowing water, seeks the path of least resistance. The tendency, as long as a difference in peripheral resistance persists, is to force at each heart beat a little more blood through the fistula at the expense of the blood flowing through the normal capillary bed N. But the blood loss from

circuit N is promptly rectified by an increase in the total volume of circulating blood, resulting inevitably, though slowly, not only in a gradually increasing volume of blood flowing through that part of the circulatory bed common to both but also in its dilatation. The determining factor in this gradual dilatation is the extent of the difference in the peripheral resistances in the two circuits, which, in turn, is determined by the size of the rent in the artery producing the fistula; by its location in the arterial tree; and by

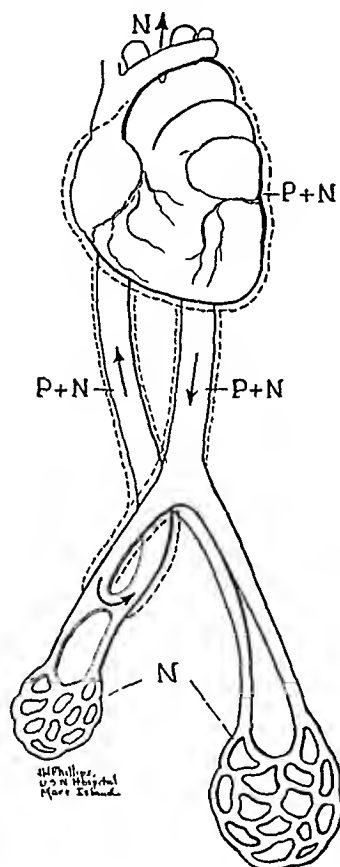


FIG. 1

FIG. 1.—The introduction of a fistula into the arterial bed introduces a *parasitic* circulation P which abstracts a certain volume of blood from the normal circulation N. The part of the circulatory bed transporting the two circulations P and N will dilate to accommodate the increased volume of blood coursing through it.

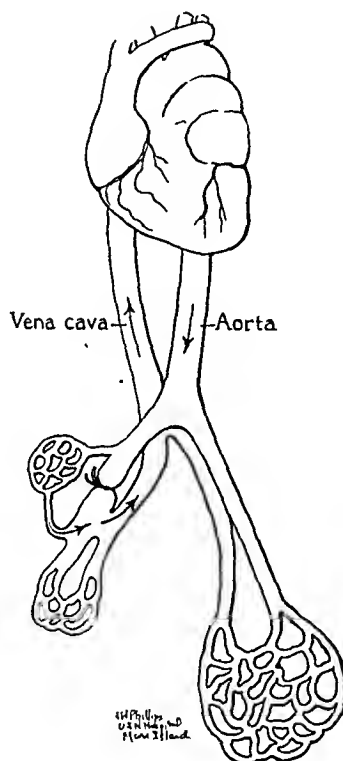


FIG. 2

FIG. 2.—Ligation of the artery alone, such as might be undertaken proximal to a simple aneurysm, is absolutely contraindicated proximal to an arteriovenous fistula. It is obvious that the blood flowing through the collateral vessels would flow back to the heart through the site of the low resistance at the fistula, thus by-passing the peripheral vascular bed. Gangrene would under these conditions be inevitable, hence the importance of differentiating a simple aneurysm from an arteriovenous fistula.

such fortuitous conditions as the amount and firmness of the fibrous tissue deposited in the process of healing around the fistula, around the vein proximal or distal to the fistula, and around the artery proximal to the fistula. If this fibrous tissue is considerable, and the fistula is small, a point will be reached rather promptly when the peripheral resistances in the two circuits will become equalized, when there will be no further increase in the volume of blood flowing through the fistula, and when no further dilatation of the

fistulous circuit will occur. Such equalization may be indefinitely postponed when the fistula lies between vessels that offer little resistance to their dilatation as in the abdomen, pelvis or upper thorax, or when the fistula itself has a minimal amount of fibrous tissue deposited around it permitting its easy though slow dilatation. The slowly progressive dilatation of the heart that occurred in a few clinical cases observed 24, 25, and 26 years<sup>5</sup> after the inception of the fistulae is explicable only on the basis of this slow dilatation of the fistula itself, producing in effect a vicious circle. The extent of the fibrous deposits around a fistula and the involved vessels may determine the great variation in the effects upon the circulation of the fistulae located in the same general region in the vascular bed. If (by chance) an injury to the vessels is accompanied by a mechanical block in the proximal vein, thus preventing an easy return flow to the heart, the effect upon the circulation and upon the heart will develop much more slowly than in the absence of such a block. Mason<sup>6</sup> records cardiac decompensation in a subclavian fistula within nine weeks of its inception, whereas, in a patient observed by me, seven years elapsed before cardiac decompensation appeared in the presence of a subclavian-jugular fistula.

A most important factor in determining the effect of a fistula upon the circulation is its location in the arterial tree. The nearer the fistula is to the heart, and the larger the vessels involved, the greater will be the discrepancy between the high pressure in the artery, and the absence of pressure in the vein, the flow of blood through the fistula being commensurate with this difference in arterial and venous pressures. As a corollary to this it may be said that the larger the injured artery, the greater will be the capillary bed normally supplied by this artery, and, therefore, the greater will be the peripheral capillary resistance beyond the point of injury or communication with the vein. Obviously, therefore, the extent of the difference between the negligible resistance in the fistulous circuit PN (Fig. 1) and the peripheral resistance in the vascular bed N beyond the fistula will be determined by the location of the fistula in the arterial tree, which, in turn, will determine not only the amount of blood diverted through the fistula but the resulting effect of the fistula upon the circulation. A fistula 15 mm. long, established between the aorta and vena cava in a dog as a lateral anastomosis, is almost invariably fatal immediately, whereas, a fistula 15 mm. long, established as a lateral anastomosis between the femoral vessels, will produce cardiac dilatation and decompensation only after years have elapsed.

Other factors influence the ultimate effects upon the circulation. If the tangential wound in the artery produces a fistulous opening larger than the proximal artery, and is, therefore, capable of transmitting more blood than this artery can supply, the arteries in the collateral bed surrounding and proximal to the fistula will open up to pour their quota into the parasitic circuit, to satisfy, as it were, its thirst for blood. This stimulus to the development of the collateral circulation is entirely due to the ease of flow through the site of decreased resistance at the fistula, and is not dependent

upon the need of the tissues beyond the fistula, as Reid,<sup>7</sup> and Lewis<sup>8</sup> have suggested.

The very occasional and rare dilatation of the artery *distal* to a fistula<sup>9</sup> is easily duplicated in the experimental animal by establishing a fistula and then tying the artery proximal to the opening. The site of diminished peripheral resistance at the fistula attracts blood from all available collateral arteries connecting with the branches of the artery distal to the fistula. The resulting greatly increased volume of blood flowing back through the distal artery into the fistulous circuit produces a dilatation of this artery distal to the abnormal communication. These experimental observations demonstrate the intimate relationship between the decreased peripheral resistance to the flow of blood through the fistula and the development of collateral circulation, and the intimate relationship also between the volume flow of blood through an artery and its resulting dilatation. Clinically, obstruction of the artery proximal to a fistula may occur due to fibrous tissue deposited in the course of healing, and, as a result, dilatation of the artery distal to the fistula may be observed.

Closing a fistula, either by digital compression or by operation, results in a reversal of all these various effects upon the circulation: the elimination of the parasitic circulation directs the blood formerly short-circuited into the fistulous circuit into the general arterial bed, distending it with a volume of blood abnormally increased in the presence of the fistula. The distension of the arterial system includes not only the already dilated heart, which temporarily becomes even more dilated, but also the arch of the aorta whose depressor fibers of the vagus nerve are stimulated producing a reflex retardation in pulse. This is a protective and natural response to the abnormally high blood pressure incident to the abnormal distension of the arterial tree. Experimentally and clinically, it has been shown that the increase in blood pressure precedes the retardation in pulse, both phenomena being dependent upon the increase in total volume of blood. There is no other possible explanation for these phenomena of increased blood pressure and retarded pulse rate on closing a fistula except on this basis of an increase in total blood volume, and no other tenable explanation has been offered by those authors reluctant to accept the clinical and experimental demonstration of this increase in total blood volume.

The overdistension, high blood pressure and retarded pulse rate following permanent elimination of a fistula are promptly rectified by a reduction in total blood volume through loss of blood plasma, as shown by an excessive urinary output and by a concentration of blood in the first 24 hours after closing a fistula. As a result of this decrease in total blood volume and of the diminution in volume flow of blood through the fistulous circuit, there occurs a rapid decrease in the size of the heart, and except for a very slight hypertrophy that has occurred during the life of the fistula, the heart will be restored practically to normal size within six to ten days.

It is obvious from the foregoing observations that a fistula large enough

to produce circulatory changes must be eliminated from the circulation to avoid a slowly progressive cardiac disability from cardiac overdistension, a complication that may occur promptly after the introduction of the fistula, or as much as 25 to 30 years later.

The following sequence of clinical events usually accompanies a fistula: dyspnea and tachycardia on the slightest exertion; an increasingly vigorous beating or "pounding" of the heart; and a progressive dilatation of the heart, followed inevitably by complete invalidism and death. There may also follow in the wake of the fistula various local manifestations, such as edema of the extremity, often elephantiasic in type, marked varicosities complicated by eczema, ulceration and occasionally bleeding.

A patient in whom an injury to a large artery is suspected is placed in a hospital for continuous and careful observations. If, under bed rest, the bleeding ceases, and there is no increase in the swelling of the limb due to an enlarging hematoma, nor evidence of developing infection, further delay in operating is advisable. An increasing hematoma at the site of the injury, or an increasing swelling of the limb which threatens the blood supply of the extremity beyond it, as shown by a cold, edematous, and pulseless leg, or arm, requires immediate operation. The operation at this stage is undertaken preferably under a tourniquet, if feasible to apply it, the hematoma is evacuated, a localized débridement is performed, and the injured vessels exposed. In the absence of any evidence of infection, and if the arterial wound is small and unaccompanied by loss of substance, a suture of the wound may be attempted. The vein is ligated to avoid the danger of an embolus either of air or blood clot. If such suture is impossible, the ligation and division of artery and vein are in order. Repeated and massive transfusions are indicated to maintain and raise peripheral arterial pressure, since this is the best guarantee that a limb deprived of its main artery will survive. Interruption of the lumbar or thoracic sympathetics either by repeated procaine injections, or by direct operation, will encourage collateral circulation by promoting vasodilation.

Should evidence of infection be present, the hazard to life is greatly increased. Under a tourniquet, if feasible, the wound is laid widely open, blood clots are removed, a débridement is performed, the injured portions of the artery and vein are excised, and the four ends of the vessels are ligated. Every nook and cranny of the wound is liberally treated with sulfathiazole powder, smeared in as an emulsion or suspension in tissue fluids, and sulfonamides are given by mouth. Penicillin is administered in maximum dosage.

If the wound to the artery appears trivial, and the diagnosis is not immediately made (and this is often the case), operation should be deferred until all danger of infection is past. Indeed, the observation that small fistulae heal spontaneously has led Reid<sup>7</sup> to advocate postponement of surgical intervention for six months. Reid emphasized also that delay in operating upon a recently formed fistula is indicated, so that the collateral circulation may be developed sufficiently to permit division of the artery if necessary. This

delay may be as short as five to six weeks, or as long as four to six months, without the life of the patient being endangered. Other benefits of delay suggested by Reid are that the injured vessels become more thoroughly healed, thus, making their dissection easier and safer, and infection is less likely to occur. For these various reasons, unless cardiac decompensation is imminent, it would be preferable to delay operation upon an arteriovenous fistula for five to six months, at the end of which time an operation may no longer be necessary. Should cardiac disability manifest itself at any time before the elapse of six months, operation should be undertaken at once. Experiments have shown that although small fistulae tend to heal spontaneously, large fistulae do not. If, therefore, evidence develops that the heart is enlarging, that the thrill and bruit are increasing rather than diminishing in intensity, that variations in blood pressure and pulse can be produced by closing the fistula, and that these variations are becoming more, rather than less, pronounced one may be certain that the opening will not close spontaneously and that it must be eliminated by operation to avoid further ill effects upon the circulatory system.

An important preoperative precaution in a fistula exhibiting cardiac disability is to prescribe complete rest in bed for 10 to 14 days preceding the operation. Digital closure of the fistula, or of the artery proximal to the communication, for 30 to 40 minutes three to six times daily will be very helpful in controlling or improving the cardiac disability. It acts, I believe, by reducing the amount of blood flowing through the fistula by encouraging fibrous contraction about the fistula. Several patients were greatly improved before operation by this simple expedient.

Following the operative closure of a large fistula which has produced a marked dilatation of the heart, it is important to restrict activity for six to eight weeks to permit the previously dilated and thinned-out cardiac musculature to become readjusted to the increase in diastolic pressure brought about by closure of the fistula. An important precaution at the operating table is also related to this extreme dilatation of the heart accompanying a large fistula. Closure of the fistula not only raises diastolic pressure by an increase in peripheral resistance, but also leads to an overdistension of an already dilated heart through a redistribution of the circulating blood, more than half of which formerly leaked into the capacious venous bed. Such overdistension of an already thinned-out cardiac muscle might easily lead to recurrence or exacerbation of the cardiac decompensation. This would be revealed at the operating table by an increased pulse rate and a lowered blood pressure on closure of the fistula, instead of the reverse. Should this occur the operator should be prepared to perform an immediate venesection in order to reduce the volume of circulating blood which had become considerably augmented during the life of the fistula.

In operating upon an arterial lesion certain fundamental principles must be observed. If a venous communication is overlooked, and the usual hunterian ligation of the artery proximal to the lesion is performed, gangrene

beyond the fistula is almost inevitable. The collateral circulation will find its way not into the capillary bed distal to the fistula, but through the fistula back to the heart (Fig. 2). Hence, the importance of accurate observations to determine whether the lesion is a simple sacculated aneurysm or an arteriovenous communication, since life itself may depend on the correct differentiation between these two conditions. The distinctive features of a fistula as compared with a simple aneurysm are: (a) the thrill and bruit are continuous but intensified during systole; (b) the slowing of the pulse and rise in blood pressure on digital closure of the artery proximal to the lesion occur only in the presence of a fistula and never in the presence of a simple arterial aneurysm, since total blood volume is not increased in the presence of the simple aneurysm; (c) the high oxygen content of arterial blood withdrawn from the veins distal to a fistula as compared to the venous blood obtained from another extremity is a distinguishing feature suggested by Brown.<sup>10</sup> If these evidences of a fistula are present, simple ligation of the artery proximal to the lesion is absolutely contraindicated.

The ligation of the artery *and vein* proximal to the fistula may occasionally be employed as a preliminary procedure in the hope that closure will be effected by thrombosis or by fibrous contraction at the site of the fistula. Usually the fistula is not cured, as the collateral channels will readily supply blood to the site of decreased resistance provided by the fistula. The ligation of the artery and restoration of the vein is definitely contraindicated, since the little blood that passes through the collateral channels will find its way promptly into the dilated venous bed, thus avoiding the distal arterial bed.

In certain appropriate cases, the Matas-Bickham<sup>11</sup> procedure of transvenous or transsaccular aneurysmorrhaphy may be attempted. Under a tourniquet, the varicose sac or the dilated vein is boldly opened, and the rent in the artery is closed by suture. The vein should be ligated above and below the fistula. The wall of the vein may be employed to reinforce the sutured rent in the artery.

Ligation of the artery and vein proximal and distal to the fistula with excision of the fistula is the operation of choice for complete cure, and the one usually most easily executed (Fig. 3). A pulsating artery that is full of blood is so much more easily identified than a collapsed vessel that isolation and mobilization of the vessels is best accomplished *without* a tourniquet, the artery proximal and distal to the fistula being isolated first for control in case of bleeding. If feasible, one should be prepared to apply a tourniquet at any time in the course of the operation.

Should complete mobilization and excision of the fistula be impossible because of involvement of important structures such as nerves embedded in dense fibrous tissue, ligation of the artery and vein proximal *and distal* to the communication without excision of the fistula is in order (Fig. 4). Under such conditions, however, the artery proximal to the fistula should be ligated *and divided*, to avoid reactivation of the fistula by the reopening of the artery through necrosis of the tissues included in the ligature.



Large pulsating aneurysmal swellings and arteriovenous fistulae of the upper thigh, above which the use of tourniquets is impossible, require careful planning and special measures lest incising the lesion engulf the surgeon and the operative site in a sea of blood, completely obscuring and defeating the object of the operation. An important maxim here, as elsewhere, is

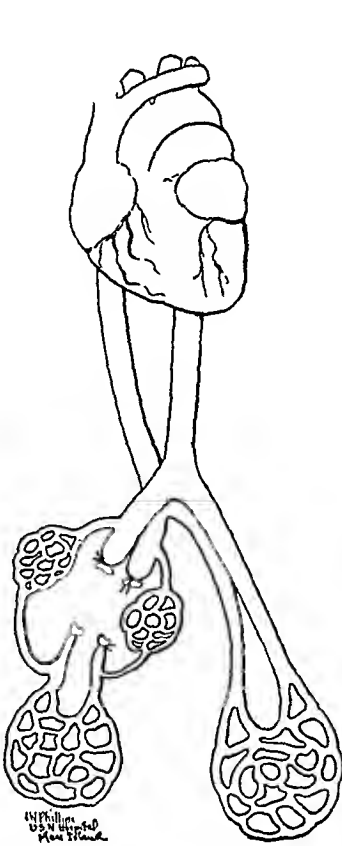


FIG. 3

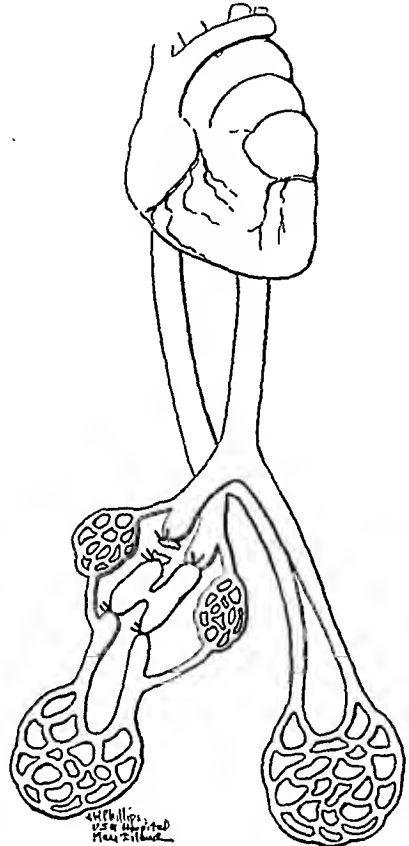


FIG. 4

FIG. 3.—The operation of choice for an arteriovenous fistula is ligation of the artery and vein proximal and distal to the fistula, and excision of the fistula. A fistula which has been present for four months or longer has usually so stimulated collateral circulation that ligation of the main artery can be performed with impunity.

FIG. 4.—If excision of the fistula is contraindicated because of difficulty in mobilization due to excessive scarring or to involvement of other important structures, such as nerve trunks, quadruple ligation, without excision, may be preferable. Under such conditions, however, the proximal artery must be sufficiently mobilized to permit ligation at two points and division of the vessel between the ligatures. Ligation in continuity invariably leads to reestablishment of the lumen and reactivation of the fistula.

not to incise a pulsating swelling without first having attained complete control of the normal artery above, and preferably also below the lesion. Complete control of the bleeding when operating upon arterial lesions of the upper thigh demands that both common and external iliac arteries be temporarily occluded. The inclusion in the temporary ligature of a segment of rubber tubing about the caliber of the artery prevents fracturing the walls of the artery, which would invite later trouble at the site of temporary ligation (Gordon Watson<sup>12</sup>). It also enables one to remove the temporary ligature without difficulty and without injury to the artery by cutting the tape

ligature on the rubber tubing. Such temporary occlusion of the common and external iliac arteries is best accomplished through a separate incision through the tendinous structures of the abdominal wall just lateral to the lower third of the rectus muscle, displacing the peritoneum upward, and exposing the common iliac artery at its origin. The lesion itself is approached through a longitudinal incision in the thigh directly over the common and superficial femoral arteries. Division of Poupart's ligament is avoided if possible. This incision for the exposure of the common iliac artery will also permit removal of the lumbar sympathetic ganglia for the production of peripheral vasodilatation, if this seems desirable.

In operations upon the large vessels of the neck, the hazards of bleeding are also greatly accentuated. To operate successfully upon arterial lesions in this area, one must be able to expose the normal artery proximal to the arterial wound for temporary occlusion. One must be able, also, to occlude temporarily the proximal vein, not only to control bleeding but also to avoid air embolism through accidental rents in the larger veins which in this region so frequently exhibit negative pressure during inspiration. To insure an exposure adequate for operations upon the subclavian and axillary vessels, it has been found desirable and practicable to resect a considerable portion of the clavicle subperiosteally. No permanent damage has resulted from such resection, since retention of the periosteum has permitted reformation of the clavicle and restabilization of the shoulder within four or five weeks. The wide exposure of important structures permitted by resection of the clavicle provides greater confidence in being at all times master of the situation should any untoward event occur, such as unexpected arterial bleeding, tears in large veins, or injuries to the larger lymphatics. On the right side, the innominate artery and vein must occasionally be temporarily occluded by tape ligatures. Resection of the medial two-thirds of the clavicle and partial resection of the manubrium will reveal these underlying vessels.

Ligation of the common or internal carotid may be accompanied by hemiparesis of the opposite side, due to nutritional disturbances in the cerebrum. Due to a collateral flow through the external carotid artery, ligation of the common carotid is less dangerous than ligation of the internal carotid artery. Whenever ligation of either the common or internal carotid arteries must be undertaken, Makins<sup>13</sup> emphatically advises also occlusion of the internal jugular vein.

The success of operations upon the large vessels depends in great measure upon the avoidance of sepsis. The strictest precautions against infection must be followed throughout, and the liberal use of the sulfonamides locally and systemically is indicated in any contaminated or potentially infected wounds. Except in the presence of actual pus, drainage in vascular surgery must be scrupulously avoided. In surgery of the large vessels, the packing or drainage of wounds is inviting almost certain disaster. Should the wound at any time following operation fill up with fluid, it is a simple matter to evacuate it under strictly sterile precautions. If there is any question of

infection, penicillin should be promptly administered in maximum dosage. If drainage of a contaminated wound seems desirable, line the wound with gauze heavily impregnated with petrolatum, but avoid touching the site of ligation or the line of suture in the artery by any foreign body such as the petrolatum drain. A drain lying against the site of ligature interferes with the protective deposition of fibrin and fibrous tissue around the ligature, and invites secondary hemorrhage through necrosis of the arterial wall at the site of ligation.

#### SUMMARY

1. The physiologic effects of an arteriovenous fistula are easily understood when the short-circuit to the heart is considered as introducing a new circulation *parasitic* upon the normal circulation.

2. The effect of such a parasitic circulation is dependent entirely upon the amount of blood transmitted to it through the abnormal communication, which, in turn, is dependent upon numerous factors: the actual size of the opening, the size of the artery, its location in the vascular tree which determines the extent of the difference between end-pressure in the artery and the absence of pressure in the vein. Further factors determining the amount of blood transmitted through the opening are such fortuitous ones as how much unyielding fibrous tissue has been deposited around the fistula, around the artery, and around the vein both proximal and distal to the fistula.

3. Immediate operation for a fistula may be necessary if the wound in the artery is accompanied (a) by uncontrollable bleeding; (b) by progressive enlargement of the pulsating hematoma of the soft tissues; or (c) by progressive interference with the development of collateral vessels by swelling of the limb through infiltration of tissues with blood under arterial pressure.

4. Operation should be postponed for five to six months if the conditions noted above permit it, because:

(a) A small fistula may heal spontaneously.

(b) Collateral circulation should have an opportunity for development in case the main artery to the limb must be ligated.

(c) Tissues infiltrated with blood will return to normal, permitting better identification of structures and easier dissection of tissues.

(d) The danger of infection is reduced.

5. Dissection of vessels is more easily accomplished if they are full and pulsating; hence, operation *without* a tourniquet is preferable whenever feasible. Control artery and vein proximal and distal to fistula in good tissues first.

6. In fistulae of the neck, exposure of normal vessels proximal to the fistula is absolutely necessary, and greatly facilitated by subperiosteal removal of the clavicle, and, on the right side, by removal of portion of the sternum to expose the innominate artery and vein if indicated.

7. In fistulae of the upper thigh, particularly when associated with false

aneurysmal sacs, both common iliac and external iliac arteries must be controlled with temporary ligatures (including segment of rubber tubing to avoid injuring the arterial wall) before incising sac or exposing the fistula through a pulsating hematoma.

8. The iliac vessels are best exposed through a separate incision paralleling and along the lateral border of the lower one-third of the rectus muscle, the femoral vessels being exposed through a separate longitudinal incision paralleling these vessels. The incision should preferably not cross the inguinal ligament.

9. The operation of choice for an arteriovenous fistula is ligation of artery and vein proximal and distal to the fistula and excision of the fistula following careful isolation.

10. If excision of fistula is impossible because of fibrous deposits and adherence of important structures, such as nerves, not only ligate artery and vein proximal and distal to the fistula, but also divide proximal artery between two ligatures to avoid subsequent reestablishment of fistula.

11. Under no circumstances ligate the artery alone proximal to an arterial lesion presenting evidence of a continuous bruit indicating a venous communication. Gangrene is inevitable following such ligation.

12. Transvenous or transsaccular aneurysmorrhaphy, with ligation of vein proximal and distal to the fistula (Matas-Bickham procedure), may be employed in selected cases if the tourniquet can be applied above the lesion.

13. Drainage in vascular surgery is rarely necessary, but if used great care should be exercised to avoid touching the site of ligation or of suture by the drain. Such a contingency increases the possibility of secondary hemorrhage.

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## ARTERIAL INJURIES IN A THEATER OF OPERATIONS

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A GENERAL HOSPITAL in a Theater of Operations receives a variety of arterial injuries. Battle-incurred arterial injuries are usually dealt with in Forward Hospitals, but not infrequently these injuries are not apparent until the patient has been evacuated to the Base, usually a matter of a few days. Arterial injuries seen at the Base may be divided as follows:

I—Traumatic vasospasm, without laceration of the artery.

II—Direct arterial injury:

A. Early results of injury.

B. Late results of injury.

III—Pulsating hematoma (traumatic aneurysm).

IV—Arteriovenous aneurysm.

I—Vasospasm is a protective response to trauma, but if the arterial tree of an extremity becomes, and remains, constricted, then thrombosis, trophic changes, fibrosis and lesions resembling Volkman's ischemic contracture may follow. It has been pointed out by DeBakey,<sup>1</sup> and Elkins,<sup>2</sup> that remote trauma may result in complete spasm of an artery. We have observed 12 patients with persistent posttraumatic vasospasm in which the arteries were not directly injured. The involved extremities were cold, cyanotic and often edematous. Vasospasm could be temporarily abolished by paravertebral injections of novocaine (1 per cent). In the more severe cases, preganglionic sympathectomy was performed, with good result. The following case history is typical of this group:

**Case Report.**—A 28-year-old, white, male, received shell fragment wounds of the right upper leg and right lower thigh in February, 1944, near Cassino, Italy. Fifteen hours later, at an Evacuation Hospital, the wounds were débrided and the shell fragment removed from the leg through an elective incision along the head of the fibula. Exploration of the posterior tibial artery showed it to be in marked spasm, but the popliteal artery could be felt to pulsate. Lumbar paravertebral injection was done immediately, as the foot was cold, with absent peripheral pulses. Three more injections were done within the next few days. The patient was admitted to this hospital 13 days after injury. The right foot was colder than the left, slightly swollen and the peripheral pulses were questionably palpable. The wounds were closed two days after admission, and it was necessary to repeat the paravertebral "block" as the foot became cyanotic and clammy. The wounds healed normally, but the foot continued clammy and cyanotic, becoming warm and pink only after "blocks." Femoral pulsations were normal, but neither the popliteal nor peripheral pulses could be felt. In all, eight paravertebral novocaine injections were done. A month after injury preganglionic sympathectomy was performed. The foot became flushed and warm in eight hours, and the peripheral pulses remained palpable.

Other patients in this group show that posttraumatic vasospasm may persist over long periods of time, and may be either segmental or may involve the entire arterial tree of the extremity. If vasospasm is not eliminated by a series of paravertebral "blocks," we feel that sympathectomy should be considered.

II—Direct Arterial Injuries.—A—*Early Results*: Direct trauma to major arteries usually leads to thrombosis at the site of injury, formation of a traumatic aneurysm, or formation of an arteriovenous fistula. The latter two were combined in one of our cases.

Ligation of the lacerated artery (and usually its concomitant vein) at the time of the initial débridement is the procedure usually carried out in most instances. The records show that few attempts at repair or end-to-end anastomosis have been attempted in the Forward Hospitals. Captain Pryor,<sup>3</sup> in studying 361 major extremity amputations performed or admitted in this hospital, found that approximately 20 per cent were done because of inadequate blood supply alone. A study of 55 patients whose arterial injuries resulted in amputation showed almost half of them (25) were due to popliteal artery injuries alone and 18 followed femoral artery injuries. In all, we have observed 29 patients whose popliteal artery was ligated. Twenty-five of them had gangrene, which required amputation (86 per cent). It may be significant that of the four whose extremities remained viable, three had lumbar ganglionectomies, and the other one had repeated paravertebral injections. It is recognized that other factors may be of greater importance in determining viability of the leg.

Our experience with the nonsuture anastomosis of blood vessels, suggested by Blakemore, Lord and Stefko,<sup>4</sup> has been limited to three patients, upon whom the procedure was done before admission to this hospital. Two of these soldiers had a viable foot, but the third developed dry gangrene of all toes. Since the anastomosis was undertaken because of laceration of the popliteal artery, we feel that the result obtained was better than that usually effected without the venous anastomosis. Peripheral pulses were not palpable in any of the three extremities, and arteriograms have shown that the medium did not go through the anastomosis.

In an effort to decrease the number of amputations secondary to arterial injury, sympathectomy has been performed upon eight patients (Table I). Two of them with popliteal ligation eventually required amputation through the leg. These two patients had been injured for five and four days, respectively, and had not received paravertebral injections. Three other patients had sympathectomy within 48 hours after popliteal artery injury, and the extremity remained viable. This series is too small for any definite conclusions, but the results suggest that early sympathectomy in major arterial injuries may help preserve a part, or all, of an extremity.

B—*Late Results*: The late results of major arterial ligation, also, deserve consideration. In a series of seven patients whose femoral or popliteal artery had been ligated, there was evidence of chronic arterial deficiency. This was characterized by intermittent claudication on walking, "muscle cramps" at rest, weak to absent peripheral pulses and trophic skin changes, as well as comparative coolness of the extremity. Preliminary paravertebral injections showed a favorable response, and sympathectomy gave excellent results (Table II). Bigger<sup>5</sup> recently reported on 29 patients with aneurysm,

# ARTERIAL INJURIES

TABLE I  
LUMBAR SYMPATHECTOMY IN "EARLY" ARTERIAL INJURIES

Case No.	Age of Patient	Preoperative Findings	Interval v.s. Injury and Sym.	Operative Result	Remarks
1	31	Ligation com. femoral. D/3 leg cold. Gangrene of 2nd toe	6 days	Probably unchanged	Supracondylar amputation required 48 hours later, as the entire gastrocnemius appeared necrotic. Extremity had been elevated on 4 pillows prior to admission. Foot became warmer following operation, but amputation at the ankle was done 10 days later for the preexisting gangrene.
2	34	Comp'd fracture tibia and fibula. Early gangrene of toes, with cold foot	13 days	Improved	
3	47	Ligation popliteal artery. Cold, discolored foot	4 days	Little change	Gas gangrene developed in the leg wound on the 6th day after injury, and amputation was done. Extensive thrombosis of vessels throughout the leg was found on dissection.
4	28	Ligation popliteal and comp'd frac. fibula. Gangrene great toe	5 days	Leg became warmer	Amputation lower 3rd of the leg was done 3 days later because of fever, necrosis of gastroc. and solcus muscles. It was felt that sympathectomy probably permitted amputation at a lower level.
5	19	Ligation com. femoral. 4 lumbar "blocks." Cold, pulseless foot	2 days	Excellent	Foot became suddenly warm about 40 hours after operation, and remained as warm as the normal one.
6	20	Ligation popliteal. 1 lumbar block. Comp'd fracture head of fibula	1 day	Fair	Skin gangrene of tips of two toes developed, but foot remained warm.
7	19	Laceration popliteal artery and vein. Foot pulseless	8 hours	Good	This patient also had a nonsuture anastomosis, using segment of saphenous vein and vitallium cuffs (Blakemore).
8	27	Ligation popliteal. Foot cold	1 day	Good	Foot remained warm and viable.

TABLE II  
LUMBAR SYMPATHECTOMY IN ARTERIAL DEFICIENCY

Case No.	Age of Patient	Preoperative Findings	Interval v.s. Injury & Sym.	Operative Results	Remarks
1	27	Ligation Common femoral. Angina crisis. Cold foot	34 days	Improved	There was marked increase in the warmth of the foot and leg and decrease in the cramping.
2	22	Ligation superficial femoral. Cool foot	30 days	Excellent	The foot remained much warmer than the uninjured extremity. Patient's walking range was greatly increased.
3	21	Ligation common femoral. Intermittent claudication	71 days	Excellent	Can walk about ten times as far, before cramping occurs.
4	21	Ligation superficial femoral. Claudication after 200 yards	86 days	Excellent	Foot remained much warmer, and claudication disappeared.
5	29	Ligation of popliteal comp'd fract. femur. Cold, swollen foot	11 days	Excellent	Preoperative "blocks" caused flushing of the foot. Postoperative, the foot could be elevated in skeletal traction without blanching as before operation.
6	22	Ligation femoral vessels. Claudication on walking	68 days	Excellent	Walking range greatly increased. Patient returned to duty.
7	20	Ligation popliteal vessels. Daily lumbar blocks for 6 days	19 days	Good	Patient had developed a small area of necrosis on heel. Foot became much warmer, and wounds healed promptly.



or A-V fistulae, followed over a period of years. He found that a high percentage of these patients had chronic arterial deficiency when the main artery had been ligated. He suggests that sympathectomy may help relieve this deficiency.

III—*Traumatic Aneurysms*.—Traumatic aneurysms (pulsating hematomata) may not be apparent until some days after injury. When present, conservative measures have been carried out unless strong indications for early intervention exist. Such indications were present in about 40 per cent of our patients with aneurysms (Table III). The remainder were returned to the Zone of the Interior. In three instances, the expansile pulsation and systolic bruit previously present, spontaneously disappeared while the patients were awaiting evacuation.

TABLE III  
TRAUMATIC ANEURYSMS

Artery Involved	Interval v.s. Injury & Oper.	Indications for Operation	Operation	Comment
Rt. axillary (3rd portion)	24 days	Increasing size of mass. Pain — Pressure on brachial plexus	Excision of artery involved. Ligation of ant. circumflex humeral. Ligation of axillary vein	Paravertebral (T 1, 2, 3) blocks with novacaine. Extremity warm. Normal union of clavicle.
Rt. axillary (2nd portion)	13 days	Severe secondary hemorrhage from aneurysm	Excision of artery involved with the "false" sac	Stellate ganglion block. Extremity warm and viable. Edema subsided in five days.
Rt. external carotid	20 days	Increasing pulsatile mass. F.B. of neck	Excision of artery involved with the "false" sac	No cerebral changes.
Lt. radial (midportion)	28 days	Superficial expansile tumor	Segment of artery and aneurysm excised <i>en masse</i>	Duty.
Rt. axillary (3rd portion)	5 hours	Tremendous hematoma. Absent radial pulse	Division and ligation axillary artery. Ligation of post. humeral and subscapular	Two paravertebral injections. Hand warm, and sensation and motion improved.
Rt. subclavian (3rd portion)	15 days	Undebrided wound of clavicle. Absent radial pulse. retained M.F.B.	Excision of lacerated segment. Subperiosteal resection medial $\frac{1}{2}$ of clavicle	Paravertebral "block." Nail bed circulation good. Plaster yoke for three weeks.
Lt. superficial femoral	38 days	Increase in mass and severe pain in extremity 7 hours previously	Common femoral isolated through separate incision. Excision of lacerated segment and aneurysmal sac.	Preliminary lumbar sympathectomy. (8 days prior).
Lt. superior gluteal	8 weeks	Sudden increase in mass, with pain. Bruit had disappeared	Excision of aneurysm	No complications.
Lt. ext. carotid	10 days	Profuse hemorrhage into mouth	Ligation of external carotid, and plication of aneurysmal sac	No cerebral changes.
Rt. popliteal	2 hours	Hematoma. Cold, pulseless foot	Ligation and division of artery and vein	Multiple paravertebral blocks. F.C.C. femur treated with leg elevated only a few inches. Extremity viable.
Lt. common carotid	0.5 hour	Hematoma. Hemorrhage from stab wound	Ligation with transfexion sutures	No cerebral changes.
Rt. common carotid	8 days	Massive sec. hemorrhage. Aneurysmal sac	Excision of bifurcation of carotid, with ligation of common, int. and ext. carotid arteries	No cerebral changes.

## ARTERIAL INJURIES

**Case 1.**—This 25-year-old male had multiple, severe battle injuries, resulting in exteriorization of the hepatic colon, a compound spiral tibial fracture, hematoma of the right anterior aspect of the shoulder, and other extremity injuries. The hematoma was partially evacuated and a drain inserted through an axillary stab incision. Three days after admission to this hospital (19 days after injury) there was sudden increase in size of the right subpectoral mass and severe "burning" pain which involved the right upper extremity. Function of the hand and forearm became greatly impaired with hypesthesia over the radial and median nerve distribution. Blood pressure, right, was 104/76, left, 130/78. The mass was expansile and a systolic bruit was present. The pain became severe and required morphine at frequent intervals.

At operation (24 days after injury), the subclavian artery was temporarily occluded through a separate incision after dividing the clavicle. The aneurysm was then opened and the lacerated axillary artery divided between ligatures. The anterior circumflex humeral was also ligated at its origin at the site of injury. The hand remained warm, and motor and sensory function improved rapidly. Two paravertebral blocks were done postoperatively.

**Case 2.**—The indication for operation on this patient was severe secondary hemorrhage 13 days after injury. The false sac and segment of axillary artery involved were excised, and stellate ganglion block performed, but there was never any doubt as to the viability of the hand.

**Case 3.**—The expansile, pulsating mass in the neck steadily increased in size. The damaged portion of the right external carotid artery and false sac were excised without any complications.

**Case 4.**—This aneurysm involved the left radial artery, and following excision the patient was discharged to full duty.

**Case 5.**—This 23-year-old, white male was shot just above the right breast. On admission to this hospital, five hours later, there was an enormous hematoma of the right axillary and right pectoral regions, absent right radial pulse, and the hand was cold. There was no bruit. There was a 15-mm. laceration of the circumflex humeral arteries, so that ligation of the three vessels was necessary. The axillary artery was divided between ligatures. The distal stump pulsated feebly. The concomitant vein was also ligated. Paravertebral injections were performed postoperatively, and the hand remained warm and steadily improved in strength.

**Case 6.**—This 19-year-old, white, male, sustained a penetrating shell fragment wound of the right clavicular region, and was in profound shock when admitted to a Forward Hospital. There was a compound comminuted fracture of the clavicle. External hemorrhage ceased, and no operative procedure was carried out. There was paralysis of portions of the brachial plexus. On admission to this hospital, 12 days after injury, the wound of entry was infected, with spicules of clavicle exposed, absent radial pulse, but a viable hand. Penicillin administration was begun 48 hours before operation. The wound of entry was excised, and the medial half of the clavicle resected subperiosteally. The hematoma surrounding the subclavian artery was undergoing organization. The artery was found to be almost divided just lateral to the anterior scalene muscle. The artery was divided between transfixion ligatures. The distal stump pulsated slightly. The postoperative course was uneventful. A figure-of-8 plaster yoke was removed after three weeks. The radial pulse could not be felt but the hand was quite warm.

**Case 7.**—This patient sustained a penetrating shell fragment wound of the left midthigh. His record stated that the wound was débrided and the foreign body was not removed. A week later the patient had two secondary hemorrhages, and a large, pulsating hematoma was noted. On admission to this hospital an expansile mass the size of a grapefruit was present on the anteromedial aspect of the left upper thigh. There was a systolic bruit present. The foot was warm, though the peripheral pulses were barely palpable. The mass increased in size, and the patient complained of pain

in the thigh at all times. The second, third and fourth lumbar sympathetic ganglia and trunk were removed as a preliminary measure, since it was felt that the aneurysm might involve both the superficial and profunda femorals, and the common femoral.

Eight days after sympathectomy the mass suddenly increased in size, and the pain became intense. The common femoral artery was temporarily occluded through a small, separate incision before exposing the large aneurysm. The aneurysm contained about 1,000 cc. of clotted and unclotted blood. The defect in the superficial femoral artery was too large for repair, so the entire segment just distal to the origin of the profunda down to a branch below the laceration was excised. There was bleeding from the distal stump. The vein was also sectioned between transfixion ligatures. The shell fragment was found in the clotted blood. The postoperative course was uneventful. The foot remained quite warm.

TABLE IV

## ARTERIOVENOUS FISTULAE

Site of Fistula	Interval v.s. Injury & Oper.	Preoperative Findings	Operation	Comment
Post. tibial (M/3)	8 weeks	Machine-like murmur. Continuous thrill. Branham's sign	Quadruple ligation, and excision of fistula	Duty.
Post. tibial (M/3)	5 weeks	Machine-like murmur. Continuous thrill. Branham's sign	Quadruple ligation, and excision of fistula	Duty.
Lt. common carotid-jugular	5 weeks	Loud murmur; strong thrill; and large M.F.B. at site of fistula	Quadruple ligation, and excision of fistula	M.F.B. 1.5 x 1.5 x 1.0 cm found to lie in the aneurysmal varix sac. No cerebral changes.
Rt. axillary vessels (P/3)	9 weeks	Right brachial 80/70. Left brachial 130/70. Branham's sign — 18 min.	Quadruple ligation, and excision. Brachial plexus neurolysis	Proximal 2/3 clavicle resected subperiosteally. Hand warm. Pulsation distal axillary stump noted.
Lt. profunda femoris vessels	6 weeks	Machine-like murmur, and large aneurysmal sac	Ligation and excision of vessels. Evacuation of large hematoma	Patient had severe pain from false aneurysm. Good pulsation post-operative.
Lt. brachial vessels (M/3)	8 weeks	Murmur and thrill. Branham's sign. Radial pulse good	Ligation of vein and endo-aneurysmorrhaphy	Arteriogram showed artery to be patent post-operatively. Hand warm. Good radial pulse.
Rt. subclavian vein (1st portion)	8 weeks	Typical machine-like murmur, and thrill. Radial pulses equal	Excision varix proximal subclavian vein and adjacent scar tissue	No definite arterial communication with the dilated varix was found. Normal findings after operation.

**Case 8.**—This patient had multiple severe shell fragment wounds. A systolic bruit was noted over the left buttocks soon after admission to this hospital, but gradually disappeared. Two months after injury there was sudden pain and increase in the size of the mass. The aneurysm was excised.

**Case 9.**—This is the only instance in which the hunterian operation was carried out. The patient had a compound fracture of the mandible and secondary hemorrhage into the mouth. The intermaxillary bands were removed and pressure made over the carotid until the external carotid could be occluded. This checked the bleeding but the wound of entry was enlarged and plication of the aneurysmal sac carried out. There were no further complications.

**Case 10.**—This patient sustained a gunshot wound of the right lower thigh, with laceration of the popliteal artery and a compound fracture of the femur. On admission, two hours later, there was a large hematoma, and the foot was cold and pulseless. The popliteal artery was divided between ligatures after evacuation of the hematoma.

## ARTERIAL INJURIES

The popliteal vein was then ligated. Repeated paravertebral injections were carried out postoperatively. The foot became cadaveric in appearance on even slight elevation, but remained viable, and the fracture healed normally.

**Case 11.**—This 39-year-old, colored, male, was stabbed in the neck with a meat knife by another neuropsychiatric patient. There was profuse hemorrhage which was partially controlled by digital pressure. Under endotracheal anesthesia, the wound was enlarged, and the left common carotid found partially divided after the large hematoma had been evacuated. The artery was ligated. There were no cerebral complications during the next six weeks, and the patient was returned to duty.



FIG. 1.—Anteroposterior roentgenogram.

**Case 12.**—This 30-year-old, white, male, had massive secondary hemorrhage into his mouth eight days after injury. There was an indurated, nonpulsatile mass in the right side of the neck, on admission, and Horner's syndrome was present. A small aneurysmal sac at the bifurcation of the common carotid was excised, necessitating ligation of the common carotid and the ends of the internal and external carotids. The excised segment showed marked atheromatous changes. There were no cerebral complications.

**IV—Arteriovenous Aneurysms.**—During the past year we have observed 13 patients with traumatic arteriovenous fistula. Seven of these were returned to the Zone of the Interior for definitive treatment later. Definite indications for operation were present in the remaining six (Table IV). There were no recurrences, gangrene, secondary amputations or deaths in any of the patients operated upon, for either aneurysm or arteriovenous fistulae.

It is important that the two conditions be differentiated, as both the local and systemic effects are different. An arteriovenous fistula is characterized

by a continuous machine-like murmur, which has been likened to the repeated whispered sound of the letter R. The palpable thrill or purr is also continuous. Branham's bradycardiac phenomenon is usually demonstrable when the proximal artery can be compressed.

Cases 1 and 2: Both patients had small arteriovenous fistulae involving the posterior tibial vessels. These were excised and the patients returned to duty.

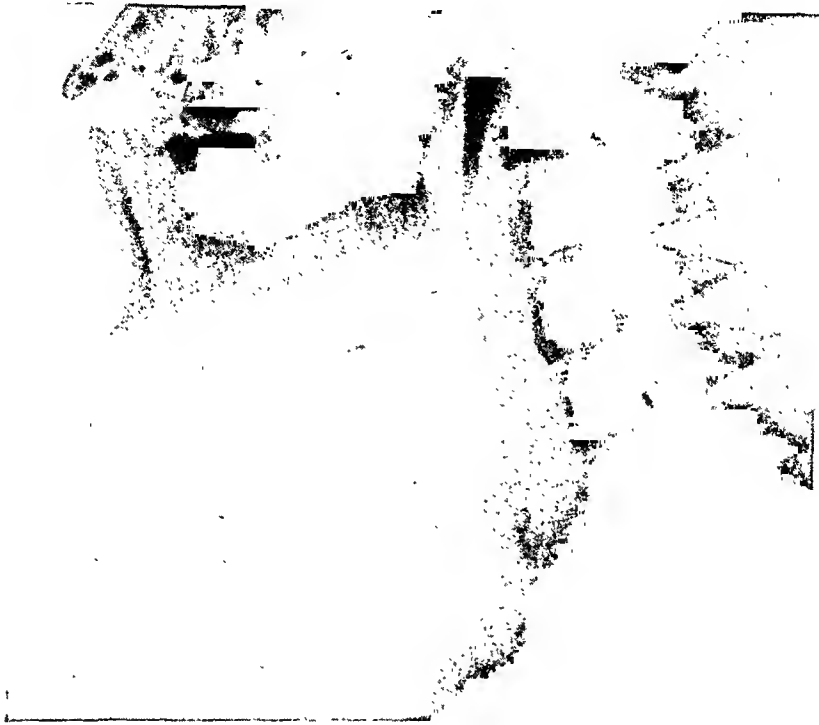


FIG. 2.—Lateral roentgenogram.

Case 3: This 20-year-old, white, male, sustained a penetrating shell fragment wound of the left infraclavicular region. A diagnosis of arteriovenous aneurysm was made 24 hours later (Figs. 1 and 2). On admission to this hospital, four days after injury, the wound of entry was healing. There was a very loud, continuous, machine-like murmur and thrill over the base of the left side of the neck. Pressure over the proximal vessels just above the manubrium caused the murmur and thrill to disappear. Brachial blood pressure determinations were equal. The murmur increased in intensity, but there was no evidence of cardiac enlargement. The patient was confined to bed because of extremity injuries as well.

At operation, a shell fragment, 1.5 x 1.5 x 1.0 cm., was found to lie within the aneurysmal varix sac, between the left common carotid artery and internal jugular vein. Quadruple ligation and excision of the sac and foreign body was carried out, as restoration of the artery was not possible. There were no postoperative complications (Fig. 3).

Case 4: This 26-year-old, white, male, sustained a perforating bullet

wound. The wound of entry was just below the medial third of the right clavicle, while the wound of exit was in the posterior axillary line. The right second rib and scapula were fractured by the bullet. The diagnosis was made, within 14 hours, at a Forward Hospital. On admission to this hospital, three days after injury, the thrill and bruit characteristic of an A-V fistula were present in the right infraclavicular space. Blood pressure, left



FIG. 3.—Ten days after quadruple ligation and excision of a common carotid-internal jugular fistula.

brachial 130/70, and right 80/70. The pulse rate slowed 18 beats per minute on compression of the proximal subclavian artery. There was some median nerve involvement. There was a progressive increase in the size of the heart shadow, though it remained within the upper limits of normal.

At operation, nine weeks after injury, the medial two-thirds of the clavicle were resected subperiosteally, to permit exposure of the vessels proximal to the fistula. The fistula was dissected out of a mass of scar tissue after the vessels had been secured both proximally and distally. Several trunks of the brachial plexus were freed from scar tissue and a small, superficial component of the median nerve was found to be divided and was sutured. The distal axillary stump pulsated. Convalescence was uneventful.

Case 5: This 28-year-old, white, male, sustained a shell fragment wound

of the anterolateral aspect of the left upper thigh. The missile traversed the left thigh, passed through the base of the scrotum, then the right thigh, fracturing the right femur. The wound of exit was on the posterolateral aspect of the right thigh. A large hematoma of the left thigh was evacuated at time of débridement.

On admission, a week after injury, the patient had a large mass in the anteromedial portion of the left thigh, which was slightly expansile, and quite tense. There was also a continuous, machine-like murmur of the upper left thigh and palpable thrill, which disappeared on compression of the common femoral artery. Skeletal traction was applied for the reduction of the right femoral fracture. A diagnosis of traumatic aneurysm and an arteriovenous fistula was made. The patient had severe pain in the left thigh, and burning and hypesthesia of the left foot and leg. The pain could not be controlled without morphine, therefore, operation was performed six weeks after injury. The foot was quite warm. At operation, the fistula was found to involve the profunda femoral vessels as well as communicating with an aneurysmal sac which contained over 1,000 cc. of old blood. The fistula was excised and the aneurysmal sac evacuated. The superficial femoral artery remained intact, so the circulation was adequate. Traction was continued until firm union of the femur was obtained.

Case 6: This 31-year-old, white, male, received multiple penetrating and perforating shell fragment wounds of the trunk and extremities. He was admitted to this hospital one month after injury. At that time, a diagnosis of arteriovenous fistula of the left midbrachial vessels was made. Compression of the artery proximal to the fistula caused a drop of 22 beats per minute of the pulse rate. On two occasions the patient had secondary hemorrhage from a small wound on the posterolateral aspect of the left arm. There was no nerve injury or cardiac enlargement. Operation was performed eight weeks after injury because of secondary hemorrhage and slight increase in the mass at the site of the fistula.

The fistula was dissected out after isolating the main vessels both proximally and distally. The vein was opened and a reparative endo-aneurysmorrhaphy was carried out, sacrificing the vein. An arteriogram, made at this time, showed the artery to be patent at site of repair. There was a good radial pulse postoperatively.

Case 7: This case was of interest because there was a typical machine-like murmur and thrill before operation, and yet no definite arterial communication could be found at operation. A 22-year-old Negro, male, received a pistol shot wound of the right side of the neck. The bullet entered just above the right sternoclavicular junction and the wound of exit passed through the scapula. For the first 12 hours the arm was cold and pulseless, then it became warm, and the pulse became normal. The patient was in a hospital in Corsica for one month, then returned to duty. Two weeks later he was readmitted because of numbness of the inner side of the arm, and a diagnosis of arteriovenous fistula of the subclavian vessels was made. The patient

was admitted to this hospital a few days later. The blood pressure of the two arms was equal, 110/70. The thrill and bruit were characteristic of an A-V fistula. However, the thrill and bruit could be obliterated by pressure proximal to the fistula *without* decreasing the volume of the right radial pulse or appreciably slowing the pulse rate. There were signs of compression of roots of C-7 and D-1, and impairment of pain and vibratory perceptions in the fourth and fifth fingers. There was no cardiac enlargement and the E. K. G. was normal.

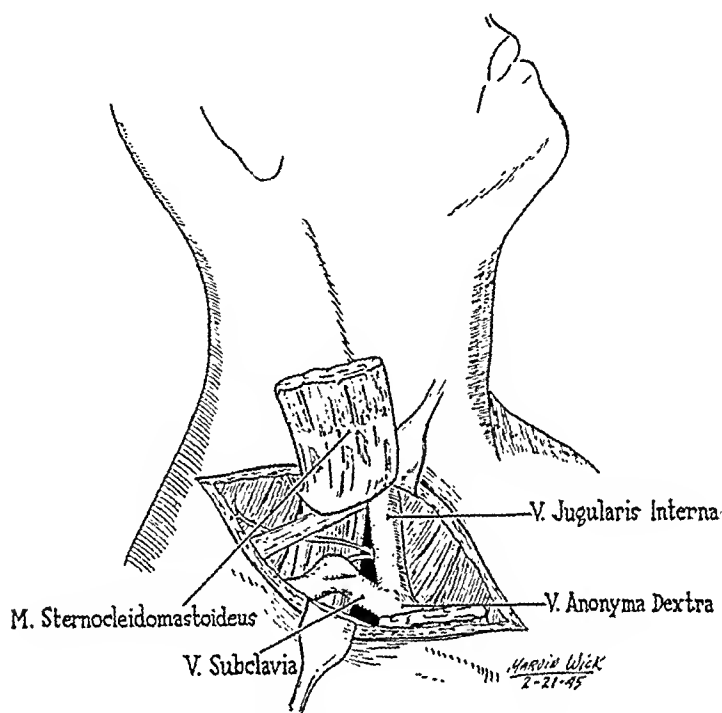


FIG. 4.—Drawing showing the angulation of the proximal portion of the subclavian vein.

At operation, the proximal portion of the subclavian vein was found to be angulated by scar tissue. At the apex of the angulation on the superior surface, the wall of the vein was quite thin, resembling a diverticulum (Fig. 4). Eddies of blood could be seen in the vein and the palpable thrill was quite marked. The thrill could be obliterated by temporary occlusion of either the proximal or distal segment of the subclavian vein. No arterial communication could be demonstrated. The involved segment, four centimeters in length, was excised. Postoperatively, the thrill and murmur were absent, and the patient was returned to full duty. Careful examination of the specimen failed to reveal any communication.

COMMENT: It is hoped that further experience with the nonsuture anastomosis, as advocated by Blakemore, *et al.*, will lower the incidence of gangrene following sudden trauma to major arteries. This method would seem especially feasible in popliteal artery injuries, since injury to this artery was followed by gangrene in 86 per cent of the patients observed in this hospital.

Early operative intervention in traumatic aneurysms was necessary in



about 40 per cent of the patients seen. This includes several patients with injuries of only a few hours' duration. The systolic bruit and expansile pulsation disappeared spontaneously in three patients while awaiting evacuation. The operative incidence in this hospital was less than 30 per cent in patients with arteriovenous fistulae, excluding those patients who were returned to duty shortly after operation. We have not seen the spontaneous closure of any of the arteriovenous fistulae.

The temporary occlusion of vessels has been accomplished by using a broad cotton tape ligature tied down on a segment of small rubber tubing laid on top of the vessel—a method suggested by Holman.<sup>6</sup> Bulldog artery clamps not being available, we have also used a screw clamp to obtain partial, or complete, occlusion of the artery after encasing the vessel in a segment of tubing of suitable size. Manual compression by an assistant just proximal to the ligature decreases the tension so that the ligature can be tightened with less danger of rupturing the intima. All vessels are divided and the ends transfixed.

The subperiosteal resection of the medial half or two-thirds of the clavicle was done in two instances of axillary or subclavian artery injuries. This gives an excellent exposure and there is little apparent deformity or loss of function postoperatively. The periosteal bed is reconstructed at the time of closure. We have applied a figure-of-8 plaster yoke for three weeks postoperatively.

#### SUMMARY

In summary, we feel that persistent posttraumatic vasospasm should be eliminated either by paravertebral injections or preganglionic sympathectomy. Second, the incidence of gangrene following arterial ligation probably may be decreased by either early, repeated sympathetic injections or by early sympathectomy. Chronic arterial deficiency is common following ligation of the main artery of an extremity and in selected cases this may be greatly improved by sympathectomy. Finally, the results in 19 patients operated upon for traumatic aneurysm or arteriovenous fistulae are presented.

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# CHRONIC HYPERTROPHIC ANTRUM GASTRITIS

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ANTRUM GASTRITIS is of the greatest clinical significance when one considers it as an ever-present differential diagnostic possibility. It has many clinical features in common with ulcer of the antral region. It has frequently deceiving similarity with a malignancy of the same region, roentgenologically and clinically.

The purpose of our study is to evaluate clinical and roentgenologic findings, to see how much reliance can be placed on them, and which cases should be sent to the gastroscopist as a last resort before surgery. We shall try to avoid, however, a shortcoming frequently found in the presentation of the subject—the presentation of the gastroscope rather than of gastritis. The instrument's value is not in doubt; but, as cystitis and nephritis can be diagnosed without the cystoscope, we should find the means of making the diagnosis of gastritis with simple, clinical methods.

The history is usually regarded as unreliable, but then it is an art to take a stomach history which is analytical and more than an indefinite report of sensations; yet, as experienced clinicians know, a good history with roentgenograms make a stomach diagnosis. In hypertrophic antrum gastritis the patient has no pain in general, but chooses "discomfort after eating, fullness, burning sensation" as terms of description. Yet, taking a sip of ice water or hot tea frequently elicits real pain, not localized but spread over the entire stomach.

At certain stages of the disease the stomach wall becomes tender to careful palpation or slight percussion. Antrum gastritis is frequently associated with cramp-like, painful sensations. Even before seeing his physician, the patient learns to avoid meat and prefers milk and a light diet. There is no seasonal let-up; the discomfort is usually persistent throughout the day and night for weeks and months. Only occasionally have we observed a case with severe clinical symptoms—weight loss, nausea, and vomiting. Bleeding, however, has often been noted. Hemorrhage leading to death has been observed. Benedict, in a recent publication, reports the incidence of hemorrhage as 19.7 per cent (43 to 213 cases). Peritonitis has occurred.

The next step in the examination should be aspiration of the stomach contents. This should not be an Ewald meal, but a fractionated aspiration after a cup of tea and a slice of buttered toast has been given. Such examination will show in chronic hypertrophic antrum gastritis a considerable incidence of hyperchlorhydria, definitely more frequent than in pangastritis. While such findings are helpful in the differential diagnosis of carcinoma, subacidity and anacidity are occasionally found, either due to increased mucous secretion or to the insufficiency of the secreting glands in later stages

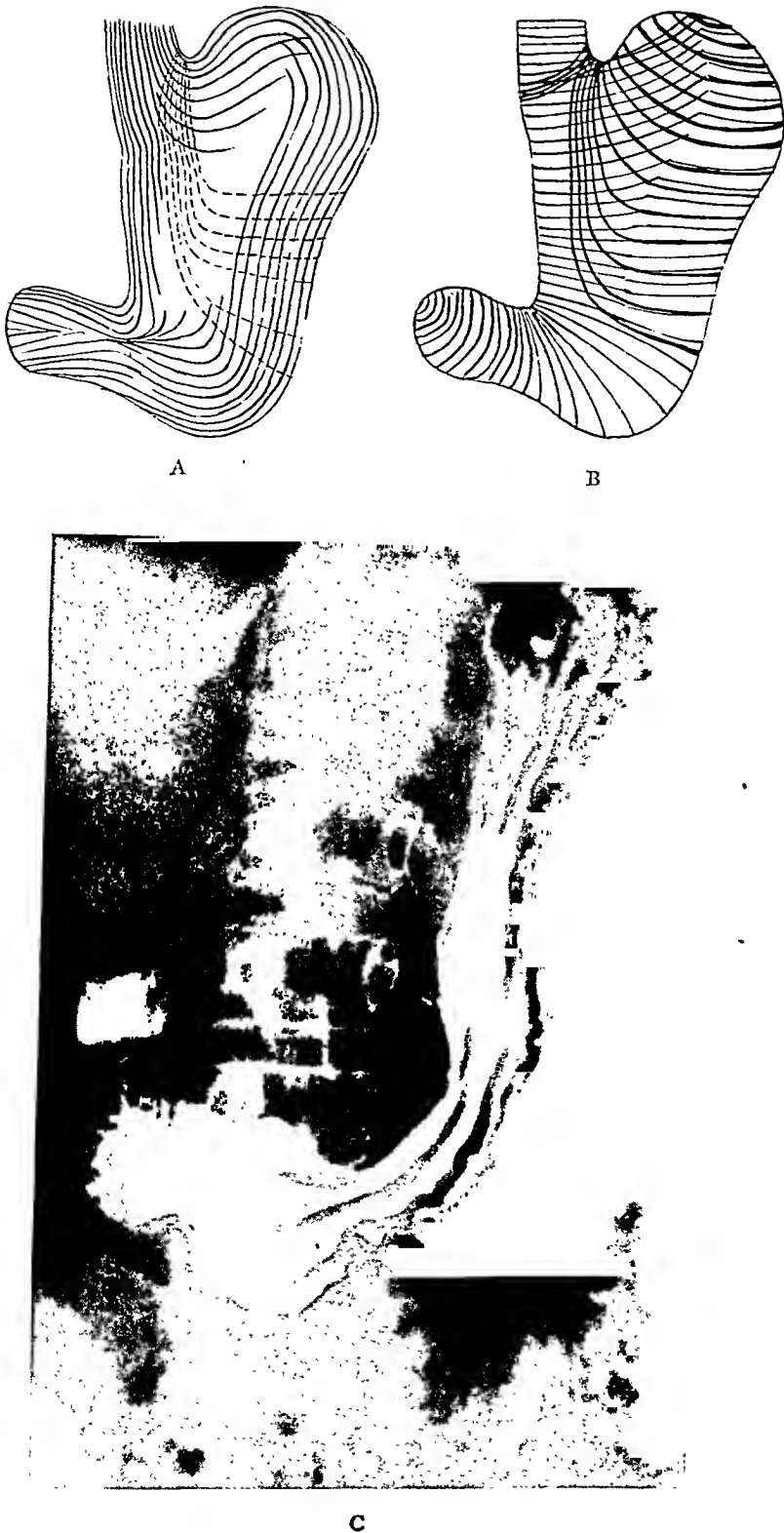


FIG. 1.—A. Longitudinal.  
B. Transverse and oblique musculature of the stomach, according to Forssell.  
C. Mucosal folds of normal stomach under prevalence of longitudinal muscle contraction.

of the inflammation. In our opinion this does not greatly detract from the considerable value of the aspiration test, as other signs of inflammation might be found in the extract—increased white cells, red cells, and mucous secretion.

The next step in our examination is the roentgenologic examination of the stomach. The roentgenologist should have on hand all the clinical data thus far obtained. There are various distinctive signs of chronic hypertrophic antrum gastritis evident in roentgenograms. Some of them might well be



FIG. 2.—Case 1: Severe hypertrophic antrum gastritis in a girl 18 years of age. Large filling defects. Note borderfold not disrupted.

accessible for direct inspection, others are beyond the reach and limitation of the optical instrument.

The term "antrum gastritis" needs justification; in fact, the entire classification of gastritis demands a review. It should not be based solely on gastroscopic findings, but should have either an anatomic or physiologic basis. The classification of gastritis, according to Schindler, has great practical merits, but is not the only one possible. He differentiates: (1) Superficial gastritis; (2) atrophic gastritis; (3) hypertrophic gastritis; and (4) gastritis of the postoperative stomach. Such a classification shows gaps and incongruities; it suggests, for example, the question as to whether there is not a form of gastritis which, in contrast to a superficial gastritis, is one of the deeper layers; forms of interstitial gastritis; and stages of development of

the disease not accessible to direct inspection, at least not to a single examination.

Such cystic and nodular forms of gastritis have been described by pathologists as gastritis cystica superficialis and cystica profunda (Lubarsch). The question is important to the roentgenologist not as a contest between specialties, but as it might account for certain discrepancies between roentgenograms and negative gastroscopic findings.

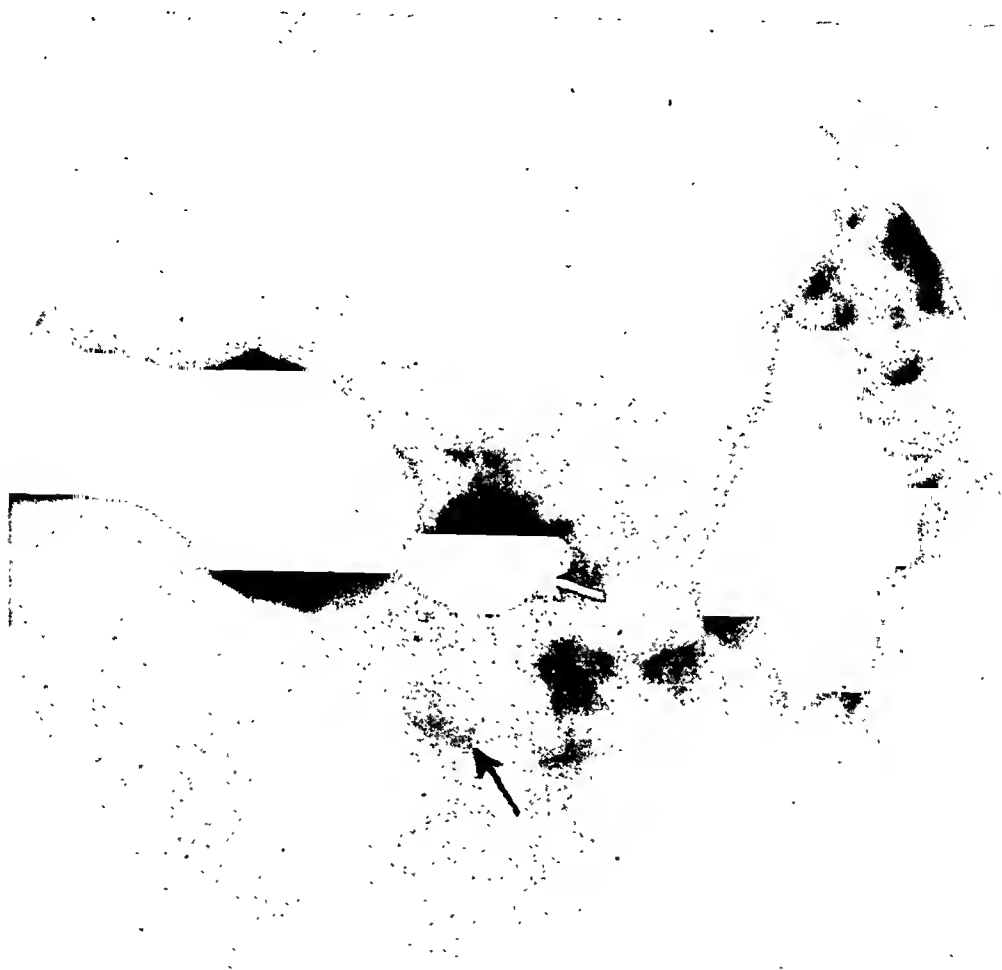


FIG. 3.—Case 1: Spot-film: Wall infiltration. Round filling defect. Antral narrowing.

Not all types of gastritis are exogenous (coming from the surface), such as is the case in alcoholic gastritis; otherwise, the considerable divergence between the advocates of the ulcer theory due to gastritis and those due to peptic-corrosive influence of the stomach secretion, would not be such a fundamental one. More frequently it is an elimination gastritis (Bourget) (coming from the depth after various infections). Gastritis has been observed accompanying influenza, cholecystitis, and even common colds; uremic gastritis is another type which comes from the depth to the surface.

Thus, the pathologist might choose a different principle of differentiation:

## HYPERTROPHIC ANTRUM GASTRITIS

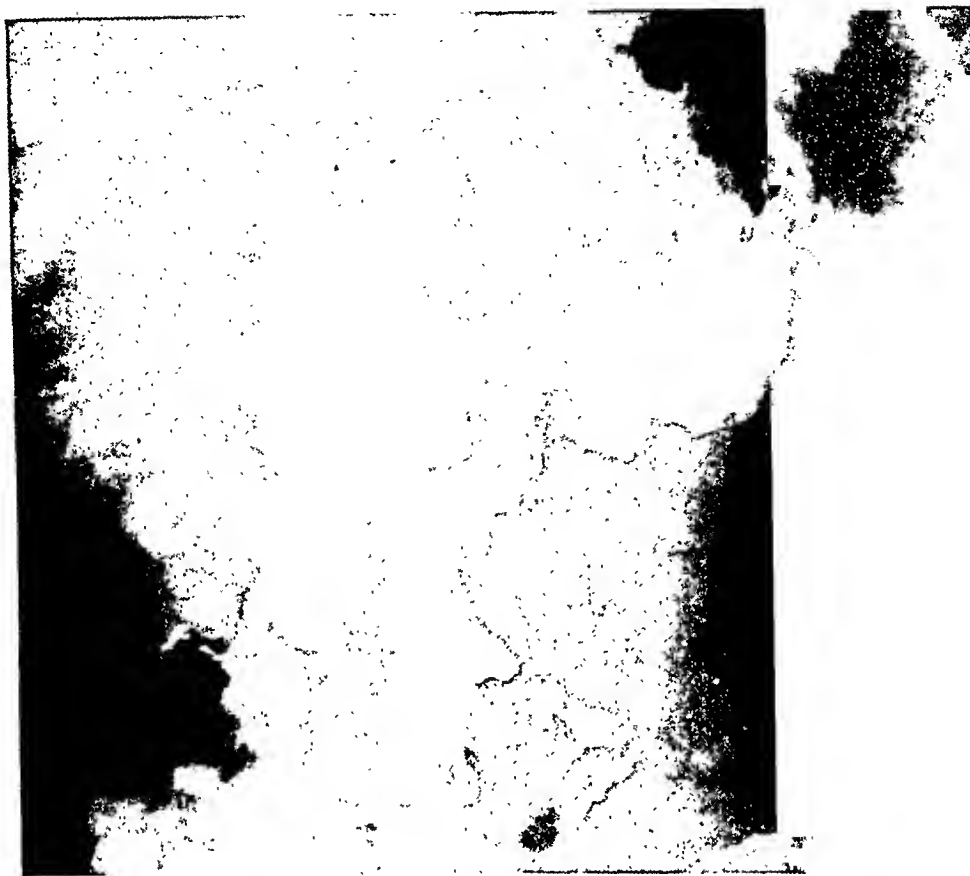


FIG. 4.—Case 1: Same case one week later. Progressive involvement.



FIG. 5.—Case 1: Six months later peristalsis restored, only slight mucosal irregularity left.

(1) Topographic, whether diffuse or localized; (2) according to the type of inflammation; and (3) he might prefer, as would the clinician, to differentiate between gastritis of different etiology or propagation—endogenous and exogenous.

The term "antrum gastritis" could mean just such a topographic des-



FIG. 6.—Case 2: Pylorus hypertrophy (Ross Golden) and Kirklin's sign: invagination of bulbar base present in hypertrophic antrum gastritis.

ignation, but as the term is not unanimously accepted, it requires clarification. As to the occurrence of gastritis limited to the antrum, veterinary medicine offers some interesting facts. Two authors, Bongart and Tantz, examined the stomach of 1,500 calves, and found at the age of four to five weeks an erosive gastritis in the second part of their stomach. When the calves were 12 to 14 weeks old, the authors found such erosive gastritis in 98 per cent; when they grew up and were one to one and one-half years old, no ulcers were found, but there were many star-shaped scars limited to the antral region. The microscopic examination proved them to be subacute or

chronic gastritis. The ulcers occur at the time when the calves are weaned, with transition from milk to raw fodder and the beginning of rumination.

This illustrates well that in addition to the chemical changes a mechanical factor plays an important rôle in the antral localization of gastritis. Experimentally induced gastritis in dogs is usually localized in the antrum.

In man we have frequently observed, roentgenologically, a pathologic involvement strictly limited to the antrum, and the anatomy of the antral region explains such localization. The antral systole creates considerable



FIG. 7.—Case 2: Spot-film showing invagination of bulbar base.

pressure within the antral chamber. A spherical pressure chamber is created between the closed pylorus and the plica angularis; this contraction being soon arrested by spasm, and later on followed by muscular hypertrophy.

It is pointed out by Ross Golden that antrum gastritis is frequently accompanied by disturbance in motility, antral spasm, and prepyloric narrowing, and he quotes Serck Hanssen, who found gastritis "invariably present with hypertrophy of the pyloric muscle."

Thus, we have a roentgenologic sign helpful in the diagnosis of chronic hypertrophic gastritis: Visible pylorus hypertrophy or antral spasm in adults.

A second sign is a change in the mucosal pattern. The significance of the mucosal pattern for the recognition of early malignancy and ulcers cannot



be too highly emphasized. How much value does it have in the diagnosis of gastritis, in general, and of antrum gastritis, in particular?

The mucosal pattern of the stomach is neither something invariably frozen, like our skin lines, nor as variable as ocean waves. Gösta Forssell, in his great work on the autoplasty of the mucosal pattern, has demonstrated and analyzed the great variation of the mucosal folds of the working stomach. In contrast to the working stomach, the fasting and empty stomach has a characteristic initial pattern. The region of the lesser curvature shows the system of the longitudinal folds, the fornix and the greater curvature, mainly

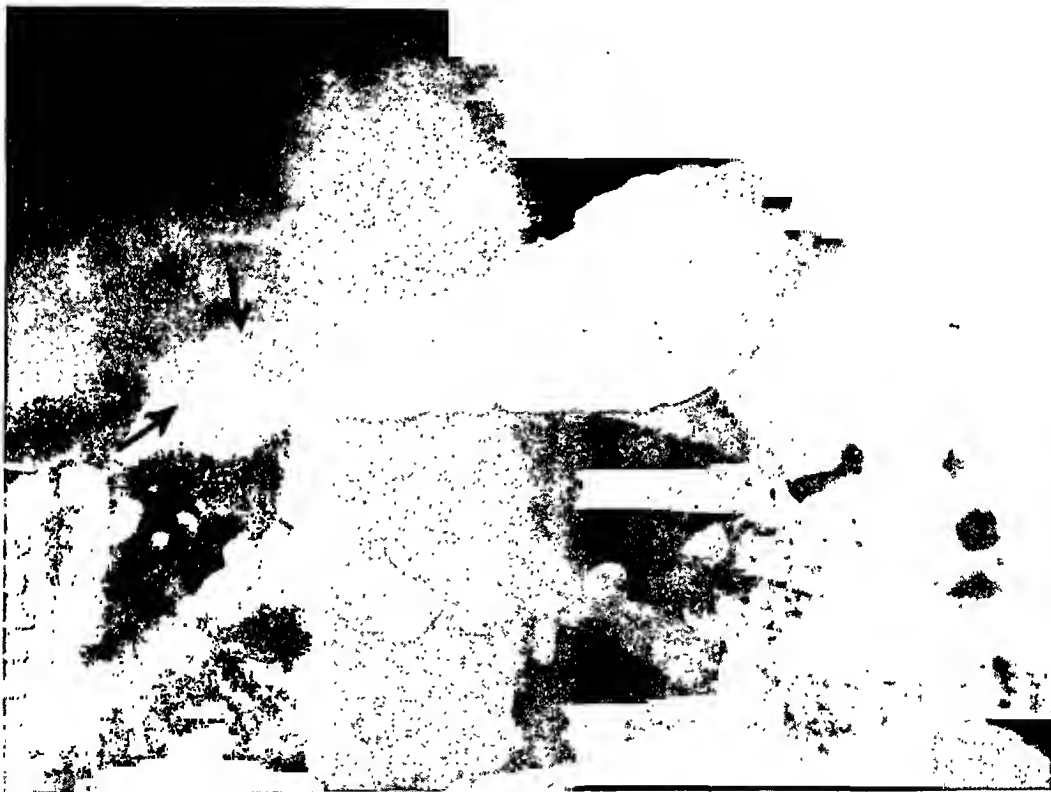


FIG. 8.—Case 3: Nodular hypertrophic gastritis. Confirmed by gastroscopy as three shallow nodular protrusions.

the system of the elliptic curved folds. In the region of the lower angle there is a quite characteristic, inverted Y-shaped fold—the plica angularis. Towards the antrum the folds are usually arranged in the pressure axis of the antrum. Several adjacent folds have usually the same direction. Upon the initial pattern is superimposed the working pattern, depending on functional requirements, hydrodynamics, and nervous impulses. After emptying, the stomach returns to its initial pattern.

How much this mucosal pattern conforms to the structure of the mucosal system is evident by comparison of the schematic drawing (according to Forssell) and a normal, regular roentgenogram taken of the fasting stomach (Fig. 1).

The constancy of the mucosal pattern of the empty stomach makes it possible for the roentgenologist to attach significance to any change in struc-

ture and direction of these folds, provided a proper and exacting technic is used. Only upon the changes in the inherent, basic design, and not upon the various autoplasmic movements can roentgenologic diagnosis rely. In spite of certain variations the basic design in the antrum is sufficiently clear to recognize any major break and deviation. Roentgenology was able to demonstrate the convergence of mucosal folds around a duodenal ulcer, the torus form of the folds around a gastro-enterostomy, and even the *Ascaris*



FIG. 9.—Case 3: Spot-film showing cobblestone appearance with preserved architecture.

worm in the duodenum. It should be relied upon to find a considerable swelling, stiffness, and deformity of the mucosal folds. This is not in contrast to Forssell's doctrine of the autoplasmic, as he states that the anatomic structure at each side facilitates the formation of the pattern characteristic of that side.

Any break of the continuity of one or several folds; granular appearance of the mucosal folds; irregular translucencies; and abrupt changes in direction if found in an empty stomach are suggestive of pathology. The differential diagnosis between antrum carcinoma and chronic hypertrophic gastritis, is, admittedly, difficult; but frequently, as our examples demonstrate, the difficulties are not insurmountable.

The characteristic, grape-like appearance of polypi in the antrum gives the same roentgenologic and gastroscopic picture, whether they are of an inflammatory or neoplastic character. The small, wart-like elevation, not so rarely found in the antrum, and the single, elevated growth, flat or lobulated, are either the end-product of chronic hypertrophic gastritis or true adenoma, fibroadenoma, papilloma, or adenopapilloma. Only histologic study may decide it.



FIG. 10.—Case 4: Muscular hypertrophy of antrum with cellular infiltration. Antrum gastritis, not carcinoma.

Spriggs, in his exhaustive, well illustrated study of polypi, found that many of the cases diagnosed as polypi were, in fact, such of polypoid gastritis. Among his 19 cases of polypoid gastritis were seven in which the polypi developed after gastro-enterostomy or accompanied peptic ulcer. Brunn and Pearl found polypi in 85 per cent of their cases localized in the antrum, and in 35 per cent they were exclusively in the prepyloric region.

These wart-like elevations are, however, sometimes spread throughout the stomach and arise from an atrophic mucosa. (See Fig. 17.) The roentgenologic appearance in the antrum is that of a cobble stone street on a rainy day: the rivulets of barium passing around the cups. The malignancy has usually

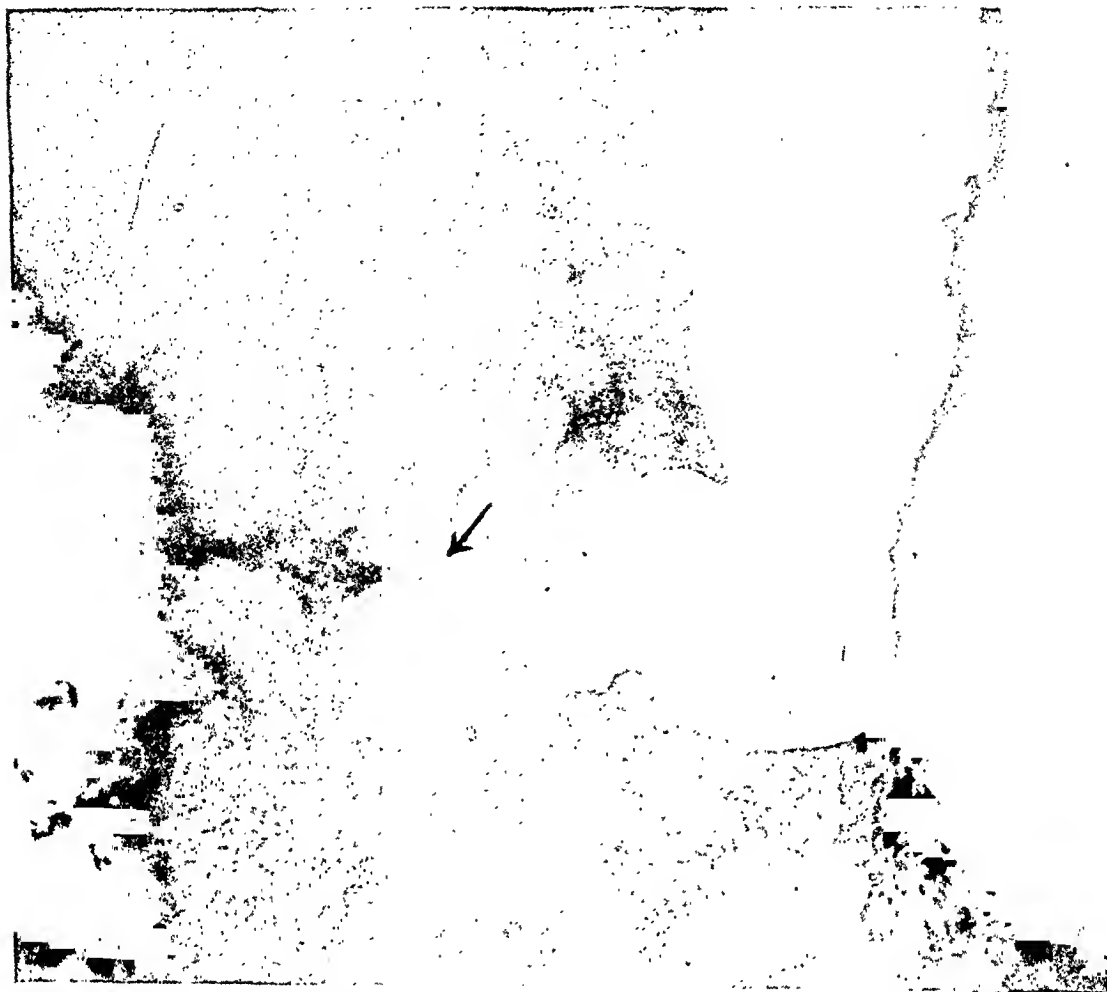


FIG. 11.—Case 5: Pylorus hypertrophy, cap deformity due to old ulcer scar. Antral defects in mucosal pattern. Antrum gastritis.

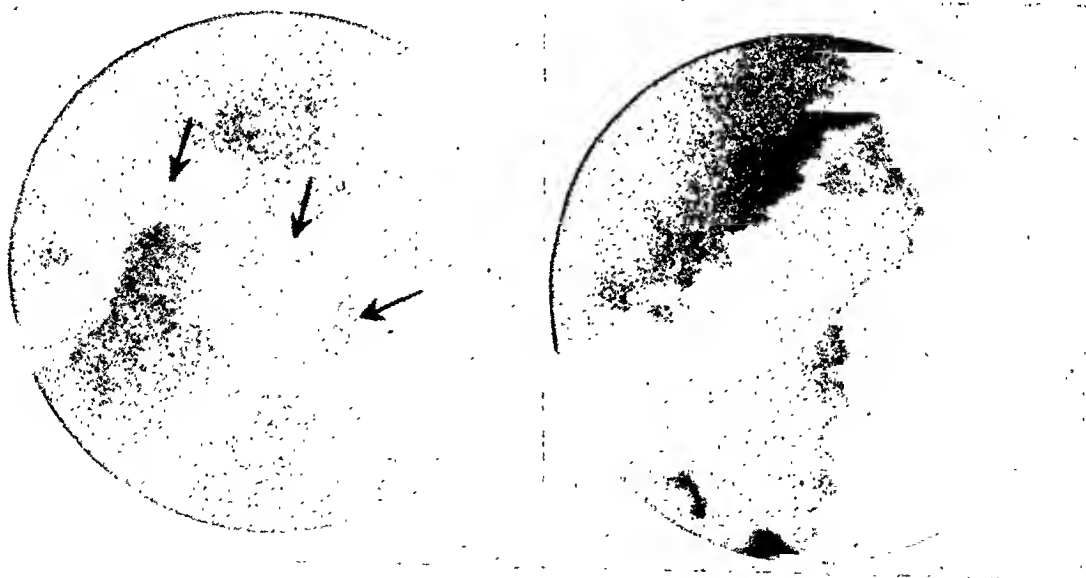


FIG. 12.—Case 5: Close-up view in spot-films.

a more vehement aspect, like a roadblock or a mine crater between the folds. Early opening of the pylorus with a deformed antrum is in favor of carcinoma; delayed opening with a similar deformity is in favor of antrum gastritis. As to differentiation between polypoid and hypertrophic gastritis on one hand, and antrum carcinoma on the other hand, the same general rule applies which Schindler gives for the gastroscopic differentiation: Regularity, granular appearance, and uniformity in size are in favor of gastritis; variability, and irregularity are suggestive of carcinoma.



FIG. 13.—Case 6: Rigid hypertrophic antral folds. Note: Border fold not disrupted. Hypertrophic antrum gastritis. Complete regression after six months.

In cases which cannot be differentiated, we do not hesitate to advise operation. If we try to find the early stages of carcinoma, even an occasionally unnecessary operation is justified. The transillumination of the antrum with a strong light is helpful before opening the stomach.

Of other reliable signs of antrum gastritis of the hypertrophic type, a sign described by Kirklin and Harris was sometimes found to be helpful: The invagination of the bulbar base; a crescenting indentation of the bulbar base might mean mucosal prolapse. We are aware that one report from the

Presbyterian hospital, in Boston, mentions six cases where the sign was found unreliable in the differential diagnosis between carcinoma and hypertrophic gastritis. We found it of distinct value, and surgeons have frequently confirmed such pictures in the absence of carcinoma as due to thickened, sausage-shaped mucosal folds rising from the prepyloric region protruding into the bulb, causing stenosis.

Gastritis being often combined with duodenitis, which is visible roentgenologically, is another helpful sign. The sign of Steuer, however, the visibility of the gastric wall as a measure of the degree of wall infiltration, is of no help in antral gastritis and doubtful in pangastritis.

If the pathologic process reaches the Y-shaped border fold between the antrum and the stomach, plica mucosa-II (Elze), the close observation of that fold is especially indicated. A sudden break in its direction or continuity is in favor of malignancy; tortuosity, rigidity, and swelling speak for gastritis.

The most common type of chronic hypertrophic gastritis in the antrum is the one in which the mucosal folds are swollen, rigid, tortuous, but without any break in the structural relief. Too many warning posts have been erected in regard to the value of such findings, some of which, in our opinion, could safely be removed.

It is correct to keep in mind that mucosal folds rise and fall under the influence of drugs; that in cardiac failure, allergy, hay fever, and asthma folds might increase in diameter. Yet, we find in alcoholics, in ulcer patients, and in uremics a certain swelling and rigidity of the folds which we unhesitatingly diagnose as hypertrophic gastritis. The follow-up after proper management usually tells us how right we were. In doubtful cases we do not hesitate to advise gastroscopy.

A critical analysis of 938 cases of gastroscopic examinations has been published recently by R. I. F. Renshaw. There were 17.7 per cent with negative roentgenologic examinations where gastroscopy revealed gastritis; yet, gastroscopy was of no value in 19 per cent of the total cases.

In differentiation between a malignant and benign lesion both methods were approximately equal. Thus, even the combination of roentgenology, clinical study, and gastroscopy will still have a certain percentage of failures. In such cases it is our procedure to employ a period of dietary management, to follow the patient's blood count and weight curve, and then advise surgery, if the changes persist in a repeat examination. The close relation which exists between chronic hypertrophic gastritis, ulcer, and carcinoma, and the frequency of malignancy in the prepyloric region, justify surgical exploration in any doubtful case.

#### CASE REPORTS

**Case 1.**—L. G., female, age 18, epigastric pains for three weeks, nausea, vomiting for three days, complete loss of appetite, tender epigastrium, free HCl 14, combined 16, blood in gastric contents 3 plus, bloodpicture: normal.

*Roentgenologic Examination:* Complete irregularity of mucosal pattern, antral wall infiltrated, stiff proliferative pressure zone.



FIG. 14.—Case 7: Polypoid defects in the antrum in a generalized gastritis of the stomach. Roentgenologic diagnosis of hypertrophic antral gastritis, confirmed by gastroscopy and later, after resection, by histologic study.

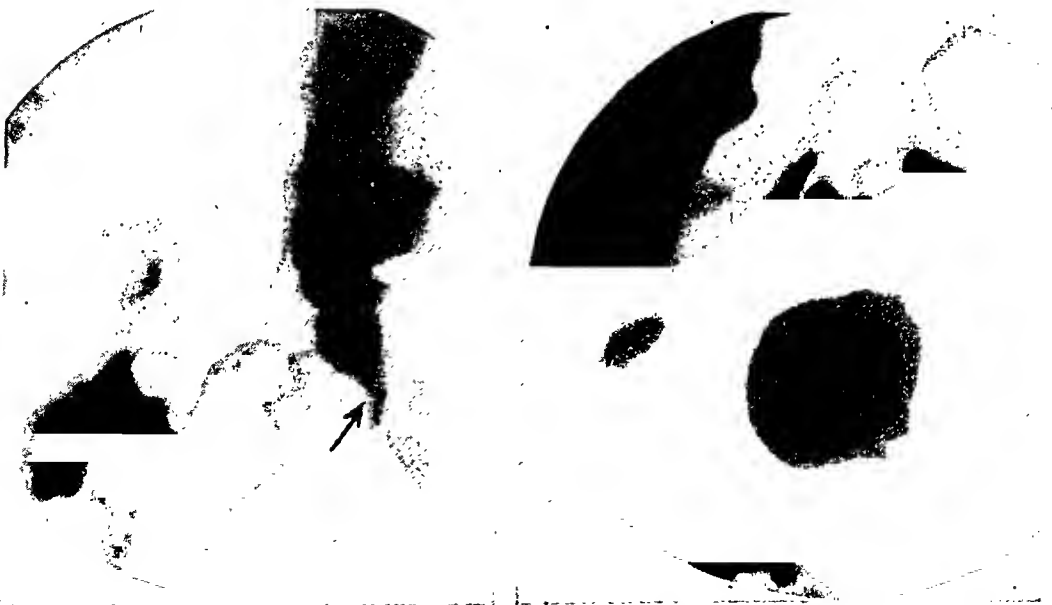


FIG. 15.—Case 7: Check-up one month later shows temporary regression, polypoid changes have disappeared, slight irregularity of medial prepyloric margin persists.

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*Diagnosis:* Severe antrum and corpus gastritis. Gastroscopy advised, delayed because of bleeding and sickness of patient. Check-up films from month to month, progressive improvement and complete cure. Has led now, for five years, a healthy, married life. No stomach symptoms.

**Case 2.**—N. L., 46-year-old salesman, complaints of five months' duration, loss of 18 pounds in five months.

*Clinical Diagnosis:* Cirrhosis of liver.

*Roentgenologic Examination:* Esophageal varicosities, but also elevated, swollen, irregular folds of antral region. Kirklin's sign present: Folds invaginated into the duodenal base.

*Gastroscopy:* Hypertrophic gastritis and pigment spot in midstomach.

**Case 3.**—H. R., 32-year-old white male, sick for five weeks, joint pain, elevated temperature, malaise, backache for three weeks, epigastric distress of five weeks' duration, pain increases with food intake.

*Roentgenologic Examination:* Multiple nodular elevations in antrum region. Gastroscopic examination advised.

*Diagnosis:* Hypertrophic antrum gastritis.

*Gastroscopy* (Dr. Schindler): Definite pathologic changes are seen in the antrum wall of the distal portion of the antrum. Three shallow, protruding, dark red nodes were seen to lie in a soft noninfiltrated mucosa.

*Gastroscopic Diagnosis:* Nodular hypertrophic gastritis of the distal antrum with an hemorrhagic ulceration.

**Case 4.**—M. D., 64-year-old male, epigastric pains over six months, severe and cramp-like. Emesis four weeks ago, constipation, weakness, 20-pound weight loss.

*Roentgenologic Diagnosis:* Circular stenosis of antrum, regular outlines—carcinoma of antrum suspected. *Operation*—April 26, 1940: No pathology of stomach seen or palpated, resection of antrum, however, performed.

*Histologic Study* (Dr. I. Davidson) (Abstract). Marked antrum gastritis with cellular infiltration deep into the muscularis: *Muscular hypertrophy*. Arteriosclerosis.

This is a case of antrum gastritis in a patient 64 years of age. Muscular hypertrophy is an important roentgenologic sign of antrum gastritis, but differentiation from carcinoma of the antrum is not always possible.

**Case 5.**—B. F., 32-year-old female, blood in stools, epigastric distress, increasing constipation for the last few years.

*Roentgenologic Diagnosis:* Duodenal ulcer, besides abnormally heavy antral folds, suggestive of antrum gastritis.

*Gastroscopy:* Did not reveal any pathology.

*Recent Roentgenologic Check-up:* Three flowerbed-like elevations still present in the antrum. Unexplained by gastroscopy.

**Case 6.**—L. A., 50-year-old male, epigastric pain after meals, localized to midabdomen, no loss in weight, stool examination negative.

*Roentgenologic Examination:* Normal mucosal lining of the stomach down to the gastric angle. The border fold is preserved, important d/D sign. Only two thick folds can be followed through the antrum. Peristalsis over antrum sluggish but persistent. Severe duodenitis visible.

*Diagnosis:* Hypertrophic antrum gastritis. Patient refused gastroscopic check-up. After conservative treatment patient shows marked improvement; now free of symptoms: stomach normal after two years' observation.

**Case 7.**—(Courtesy of Doctor Staple). S. T., 46-year-old male, lived for four months only on milk, toast, and cottage cheese; cannot digest any meat, has diarrhea, foamy stools, gastric contents: 10/34 (15 min.), 31/45 (35 min.), 32/46 (50 min.), 6/43 (70 min.), much mucosa admixed.

*Roentgenologic Examination.*—September 22, 1941: Besides an ulcer niche at the



lesser curve of the stomach, the rugae of the antrum show several sharply outlined fillings defects. Peristalsis passes over this area; moderate pyloric stenosis.

*Diagnosis:* Antrum gastritis with polypoid fillings defects. Gastric ulcer.

*Gastroscopy* (Doctor Schindler): Definite mucosal changes were seen in the great curvature, depth-I., there the mucosa was dull, being cut into small polygons by many black creases and crevices. The folds were not affected. No ulcer was found in the usual ulcer area above the angulus, but the upper portions of the posterior wall showed, again, swellings and formation of nodes.

*Gastroscopic Impression:* (1) Localized hypertrophic gastritis. (2) Lues.

*Roentgenologic Check-up.*—October 22, 1941: Marked improvement; round defects in antrum have disappeared, but rugae are still thickened; ulcer niche as before.



FIG. 16: Serum reaction: Acute swelling of mucosal folds occurred after blood transfusion, imitating hypertrophic gastritis.

*Gastroscopic Check-up:* Antrum and pylorus normal. A few nodules between the folds of the body were the only marks of the former severe hypertrophic gastritis.

*Gastroscopic Impression:* Remnants of hypertrophic gastritis.

*Operation.*—September 29, 1942: *Pathologic Findings:* Mucosa appears hypertrophic, rugae are distinct; about 10 cm. from pylorus is an area of induration, 3 cm. in diameter, the center of which presents an ulcer measuring 5 mm. The pylorus appears thickened, and there is moderate fibrosis of the duodenum beyond.

*Microscopy:* No evidence of a malignancy; chronic gastric ulcer; hypertrophic gastritis.

#### CONCLUSIONS

Chronic hypertrophic gastritis presents an ever challenging diagnostic problem, as it has clinical and roentgenologic features in common with ulcer and malignancy of the stomach.

The special problem here under discussion is that of chronic hypertrophic

## HYPERTROPHIC ANTRUM GASTRITIS

antrum gastritis. There are certain anatomic and physiologic reasons for the frequent occurrence of such hypertrophic gastritis in the antral region.

The combination of clinical study, roentgenology, and gastroscopy permits a high degree of differentiation; yet, there is still a significant percentage of errors, as high as 20 per cent, and the search for simple diagnostic and roentgenologic signs should continue.

Roentgenologic signs of chronic hypertrophic gastritis are found more frequently in the antrum than elsewhere, or in gastritis of different type (atrophic). Some of these signs, such as Ross Golden's antrum hypertrophy,



FIG. 17.—Residues of a polypoid hypertrophic gastritis in an atrophic mucosal field.  
Specimen.

Kirklin's base prolapse, and Steuer's wall symptom, are reviewed and briefly evaluated.

The constancy of the initial relief of the stomach in contrast to the variability of the working relief is stressed. Roentgenologic and differential diagnosis should be based upon the minute observation of the initial relief of the mucosa. Any vehement break in the contour and architecture of the mucosal pattern is suggestive of malignancy. Rugosity, stiffening, and widening of the folds, with preserved architecture, is highly suggestive of antrum gastritis, if supported by a history of pain and not contradicted by the clinical symptoms.

Early opening of the pylorus combined with antrum lesions is in favor of carcinoma; delayed opening is in favor of antrum gastritis. Polypous gastritis has a pathognomic roentgenologic appearance, but whether the process is of chronic inflammatory origin or neoplastic can only be decided by histologic examination.

Surgical intervention should not be delayed in doubtful cases beyond a limited period of medication and dietary management.

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# EXPERIENCES WITH THE MILLER-ABBOTT TUBE\*

## A STATISTICAL STUDY OF 1000 CASES

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IN DECEMBER, 1937, the Miller-Abbott tube was introduced at the Presbyterian Hospital as a therapeutic and diagnostic instrument under the supervision of the surgical residents. Its use spread rapidly and there has been a daily average of six to ten, at times twelve, tubes in use on the Surgical, Gynecologic, Obstetric, Genito-urinary, Neurologic and Children's Services of the Presbyterian Center. To meet this demand, Dr. A. O. Whipple (Director of Surgery), in 1939, assigned the entire supervision of tubes and records of their use to a graduate nurse. She fills out a mimeographed sheet for each tube case. This information is transcribed to punch cards in the Record Room. Approximately 1,100 such records are now completed, and this paper is a statistical review of 1,000 of these cases.

I have personally reviewed 500 of these charts and found the results as recorded in close agreement with those of this entire statistical study.

The Miller-Abbott tube has made the small intestine accessible for physiologic observation, diagnosis and therapy.

Used prophylactically before operation, the tube has been successful in decreasing the incidence and clinical severity of postoperative ileus associated with operations upon the small intestines, large herniae, resections of the colon, and in the presence of peritonitis.

In right colectomy its advantages have been so striking that its rather universal use has permitted a single-stage resection to displace the formerly considered more conservative method of two-stage resection, with enterostomy.

Whereas, it has also been useful in deflating the small intestine following resections of the left colon and rectum, it has not been as effective in these cases in deflating the remaining colon and, thereby, obviating the necessity of a proximal colostomy.

Postoperatively, it has deflated the stomach, but it should not be used primarily for this purpose. Its greatest function is deflation of the small intestine.

This tube has been a means of preoperatively diagnosing the presence and site of small intestinal tumors, foreign bodies, adhesions, kinks, bands, bleeding sites and malformations.

At operation, it has served as a guide to the site of obstruction. It has also permitted the small intestine to be, so to speak, pleated on the tube, thereby, facilitating the retraction of the small intestine from the operative area.

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\*Read before The New York Surgical Society, March 14, 1945.

Postoperatively, it has maintained small intestinal deflation, which has improved the circulation in the intestinal wall, thereby, permitting more normal peristalsis and absorption, has aided wound healing of an anastomotic site, decreased the incident of fistulae and, in the majority of cases, has been an adequate substitute for enterostomy.

It has been a means of administering fluids, proteins, sodium chloride, glucose and medications—but this function, in our hands, has been of secondary importance.

It has been a most important factor in reducing the mortality of mechanical and paralytic ileus. Leigh and Diffendorf,<sup>1</sup> in 1939, reported a mortality of 6.5 per cent in 182 cases of acute mechanical ileus from the Presbyterian Hospital which had been treated with the Miller-Abbott tube, with and without operation. From the same institution Smith and vanBeuren<sup>2</sup> reported a mortality of 18.4 per cent in 103 cases of acute mechanical ileus which had been operated upon without the use of the Miller-Abbott tube.

The cooperation of the Roentgenologic Department is necessary to obtain the maximum information and results from the use of this tube. Fluoroscopic observations and roentgenograms, with and without a barium mixture *via* the tube, have given diagnostic information which otherwise could only have been obtained by celiotomy. Barium may stop locally, pass on, or be regurgitated into proximal loops. It may advance but the tube may not, thus, indicating the degree of obstruction. The tube may be retarded by an obstructing kink, band, adherent loop, foreign body, tumor, inflammation or edema of the wall or extrinsic pressure. Multiple partial obstructions may be demonstrated.

The most important clinical fact connected with the use of the Miller-Abbott tube is the assurance that intestine with compromised blood supply is not present while the tube is being used. In mechanical ileus the pain is colicky, cramp-like, with free intervals. In ileus with compromised blood supply the pain is continuous. In mechanical ileus the pulse rate, temperature and white blood cell count are, as a rule, not elevated. In strangulation ileus the pulse rate and temperature increase with the duration of strangulation, and there is usually a corresponding rise in the white blood cell count. In mechanical ileus tenderness and muscle spasm is not noticeable. In strangulation ileus tenderness is usually marked over the area of compromised intestine. The differential diagnosis between these two types of ileus is of the greatest importance—for if strangulation ileus is present, delay in operation is not warranted.

The proper use of the Miller-Abbott tube may be life-saving. It needs one specially trained in its passage, familiar with its indications, and capable of observing it often enough to recognize the accomplishment of its functions, or detect indications of its failure and quickly test and adjust it. In contrast to this, the occasional and haphazard observations by untrained house and attending staffs has, unwarrantedly, more and more, discredited the use of

this tube and caused it to be discarded as ineffective, and this, according to our experience, is unjustified.

#### TECHNIC OF INTRODUCTION

The tube should be used as follows: The nasal passage is inspected for adequate patency; it, together with the pharynx, is anesthetized (2% butyn or Cocaine); the balloon is folded umbrella-like back over the tube, well lubricated, and with the patient partially upright, it is passed through the nostril into the stomach to the 60-cm. mark. Sipping water aids its more rapid passage. The stomach is deflated of gas and fluid with a syringe, then two to three cubic centimeters of metallic mercury is introduced into the deflated balloon. Ten to 15 cc. of air is necessary to push the mercury into the balloon. This air is then aspirated. The patient then lies on his right side and the tube is further introduced to the 75-cm. mark. The tip may be placed at the pylorus, under the fluoroscope, with the tube lying along the greater curvature. It is held lightly by adhesive to the nose (*not* the cheek), for if the slack lies along the greater curvature, there is sufficient tubing in the stomach to allow the tip to pass through the pylorus without introducing more tube, which may coil.

The progress of the tube can be noted by fluoroscopy and recorded by roentgenograms. The possibility of damage to the patient's skin by over-exposure to the roentgen ray must be borne in mind.

Its passage through the pylorus is facilitated by manipulation under the fluoroscope. This requires experienced observations in a minimum of time. If fluoroscopic observations are not used, clear fluids may be taken in order to propel the tube to the pylorus. Once through the pylorus, the nasal tape is removed and the balloon is inflated with 10 to 20 cc. of air, and allowed to progress of its own accord. Peristalsis carries the inflated balloon downward, causing a noticeable tug at the nose. In paralytic ileus the tube may not advance rapidly, and requires more attention by suction with a syringe to deflate atonic coils of intestine. When the tube is not carried on by vigorous peristalsis it may be advanced by the patient or nurse two inches each two to four hours, but no faster, lest it coil in the stomach. This much slack in the stomach may allow the tube to advance with less vigorous peristalsis, but the possibility of it coiling should be kept in mind and checked by fluoroscopy. Patients are so grateful for the relief after gastric deflation that they usually cooperate with subsequent tube care. The position of the tube tip can be determined (1) by aspiration of bile or jejunal contents; (2) by the time required for fluid by mouth to be aspirated; (3) by lack of resistance to inflation of the balloon if it remains in the stomach; and (4) by roentgenograms or fluoroscopy. We do not hesitate to transport sick cases to fluoroscopy for observation and manipulation of the tube.

The time, amount and character of the aspirated fluid should be charted. The hematocrit, plasma protein and blood chloride should be followed. Sodium chloride replacement should be approximately five grams for each

TABLE I  
AGE INCIDENCE

0-9.....	2
10-19.....	32
20-29.....	96
30-39.....	192
40-49.....	214
50-59.....	214
60-69.....	164
70-79.....	72
80-89.....	12
90, over.....	2

SEX INCIDENCE

Male.....	436	Female.....	564
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TABLE II  
TYPE OF CASE

Small bowel ileus:	
Paralytic.....	308
Mechanical.....	299
Due to vascular lesion.....	2
Large bowel obstruction.....	100
Small bowel prophylactic:	
Preoperative.....	151
Postoperative.....	84
Large bowel prophylactic:	
Preoperative.....	108
Postoperative.....	15
Diagnostic intubation.....	153
Therapeutic intubation.....	61

TABLE III  
SPECIFIC CAUSE OF ILEUS

Peritonitis.....	154
Pneumonia.....	15
Disease of C. N. S.....	3
Gangrene—strangulation.....	20
Bands and adhesions:	
Early postoperative.....	47
Late postoperative.....	127
Without previous operation.....	16
Diverticulitis.....	19
Volvulus.....	17
Intussusception.....	3
External hernia.....	32
Neoplasm.....	19
Regional enteritis.....	20
Postoperative distention.....	183
Hypoproteinemia.....	30

TABLE IV  
OTHER CAUSES FOR INTUBATION

Peritonitis.....	35
Resection.....	142
For site of obstruction.....	142
For site of bleeding.....	11
Physiologic study.....	1
Feeding.....	9

TABLE V  
SITE OF OBSTRUCTION IN MECHANICAL ILEUS

Not disclosed.....	228
Duodenum.....	10
Jejunum.....	82
Ileum.....	321
Cecum.....	59
Ascending colon.....	42
Transverse colon.....	48
Descending colon.....	73
Sigmoid.....	8
Rectum.....	36

TABLE VI  
DURATION OF SYMPTOMS BEFORE INTUBATION

0-11 hours.....	52
12-23 hours.....	61
24-47 hours.....	74
48-71 hours.....	88
3-4 days.....	122
5-6 days.....	53
1 week.....	4
2 weeks.....	39
3 weeks, or more.....	242

TABLE VII  
DISTENTION BEFORE INTUBATION

None.....	243
Slight.....	154
Moderate.....	316
Marked.....	197
Dilated loops (by x-ray).....	412
Fluid levels (by x-ray).....	247

TABLE VIII  
TIME REQUIRED TO CONTROL SYMPTOMS

Not controlled.....	182
0-5 hours.....	112
6-11 hours.....	63
12-23 hours.....	163
24-47 hours.....	122
2-4 days.....	135
5 days, or more.....	30

TABLE IX  
TIME REQUIRED TO PASS PYLORUS

Incomplete.....	33
Failure.....	221
1-2 hours.....	91
3-5 hours.....	95
6-11 hours.....	63
12-23 hours.....	220
24-47 hours.....	129
2-4 days.....	118
5 days or more.....	20

TABLE X  
TIME REQUIRED TO REACH CECUM OR OBSTRUCTION

Not reached.....	361
0-23 hours.....	34
24-47 hours.....	52
2 days.....	50
3-4 days.....	105
5-6 days.....	77
1 week, or more.....	31
Not necessary.....	268

TABLE XI  
TOTAL TIME OF INTUBATION

0-47 hours.....	54
2-5 days.....	434
6-9 days.....	310
10-13 days.....	103
14-20 days.....	68
3 weeks, or more.....	15

TABLE XII  
CAUSE OF FAILURE TO PASS PYLORUS

Not possible.....	80
Not necessary.....	109
Poor management.....	17
Hiccough.....	4
Pylorospasm.....	1
No x-ray guidance.....	604

# THE MILLER-ABBOTT TUBE

TABLE XIII

## ROENTGENOLOGIC GUIDANCE

Not used.....	339
Used.....	543
Placed at pylorus at x-ray, on first attempt.....	239
on second attempt.....	43
on third, or more attempts.....	24
Manipulated through pylorus at x-ray.....	256
Passed spontaneously after placing at pylorus.....	144
Obstruction demonstrated by failure to advance.....	106
by barium.....	100
Patency of bowel demonstrated by tube at cecum.....	92
by barium.....	93
Barium studies—paralytic intestine.....	14
dilated loop.....	38
constriction.....	75
Angulation.....	62
filling defect.....	8
other—specify.....	50
X-ray diagnosis confirmed.....	85

TABLE XIV

## TIME OF EXPOSURE AT FLUOROSCOPY

1-4 minutes.....	71
5-9 minutes.....	117
10-14 minutes.....	92
15-19 minutes.....	62
20-29 minutes.....	44
30 minutes, or more.....	38

TABLE XV

## OPERATION

None.....	444
Exploratory.....	73
Division of adhesions.....	105
Resection.....	155
Enterostomy.....	24
Cecostomy.....	28
Colostomy.....	27
Enterocolostomy.....	6

TABLE XVI

## USE OF TUBE

Removed before operation.....	52
Used as guide during operation.....	37
Left in place postoperatively.....	295
Allowed to advance postoperatively.....	277
Suction continued:	
0-23 hours.....	44
24-47 hours.....	75
2-4 days.....	300
5-6 days.....	170
1 week, or more.....	143

TABLE XVII

## TREATMENTS USED WITH INTUBATION

High protein therapy.....	81
Vitamin therapy.....	53
Poultice, rectal tube.....	284
Rectal.....	605
Pitressin.....	71
Prostigmine.....	124
Morphine.....	446
Chemotherapy.....	315
Gastric lavage.....	52
Gastric suction.....	128

TABLE XVIII

## FLUIDS AND TRANSFUSION

Parenteral fluids required:	
1 day.....	50
2 days.....	96
3-4 days.....	282
5-6 days.....	205
7-13 days.....	183
2 weeks, or more.....	48
Transfusion:	
whole blood.....	345
split protein.....	2
plasma.....	48
Fluid balance followed by hematocrit.....	676

TABLE XIX

## MILLER-ABBOTT TUBE

Comparison of Intestinal Drainage with Fluid Intake (Oral)	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
Drainage exceeded intake:							
by more than 2,000 cc.....	21	21	20	9	6	1	4
by 1,500-2,000 cc.....	15	22	17	10	4	1	1
by 1,000-1,500 cc.....	38	34	16	17	5	5	3
by 500-1,000 cc.....	69	64	59	44	11	12	4
by 0-500 cc.....	223	156	90	55	37	18	10
Intake exceeded drainage:							
by 0-500 cc.....	188	168	158	103	65	41	17
by 500-1,000 cc.....	99	138	135	100	71	48	21
by 1,000-1,500 cc.....	62	95	96	100	72	39	28
by 1,500-2,000 cc.....	35	44	46	38	32	36	25
by more than 2,000 cc.....	26	33	38	41	39	31	23
Equal.....	71	57	43	28	11	7	7



TABLE XX

COMPLICATIONS OCCURRING WITH TUBE *in situ*

None.....	834
Trivial:	
Sore throat.....	129
Sore nose.....	20
Earache.....	11
Eye pain.....	1
Other trivial complications.....	2
Serious:	
Ulceration.....	2
Perforation.....	1
Hemorrhage.....	3
Other serious complications.....	5

TABLE XXI

## SYMPTOMS RECURRING AFTER DEFLATION

Early.....	140
Late.....	36
None.....	668
Gastric distention.....	132
Small intestine distention.....	119
Partial withdrawal of tube required.....	54
Second deflation required.....	68
Operation required:	
Immediate secondary.....	27
Delayed primary.....	15

TABLE XXII

## ACCIDENTS IN INTUBATION

None.....	834
Requiring replacement.....	56
Not requiring replacement.....	11
Knotting of tube.....	10
Leaking balloon.....	15
Broken balloon.....	7
Fluid in balloon.....	13

TABLE XXIII

## CASES WITH MORE THAN ONE INTUBATION

2nd intubation.....	79
3rd intubation.....	10
4th intubation.....	5
5th intubation.....	2
6th intubation.....	1
Use of mercury:	64
Used 2 cc.....	50
Used 3 cc.....	14

TABLE XXIV

## SUMMARY

Intubation:	
Successful.....	751
Unsuccessful.....	219
Incomplete records.....	30
	<hr/>
	1,000
Result:	
Improved.....	786
Unimproved.....	80
Died.....	100
Incomplete records.....	34
	<hr/>
	1,000

liter of intestinal contents aspirated. Continuous aspiration with the tube tip in the jejunum returns one-half to two-thirds of the fluid taken by mouth, whereas, about one-third returns with the tip in the ileum.

If redistention along the tube proximal to the tip occurs, the tip should be withdrawn until it lies in the upper jejunum and again be allowed to descend and deflate the redistended loops. The stomach may become distended while the tube tip is deflating the jejunum, in which case gastric lavage with a Levine tube may be necessary. The Miller-Abbott tube should be clamped and left *in situ* for 24 hours, and not removed until the obstruction is relieved or passed; or the tip has reached the cecum; or the character of the aspirated fluid becomes normal intestinal contents, and the Roentgenologic Department agrees that its diagnostic possibilities have been exhausted.

The tables are a statistical study of 1,000 cases at the Presbyterian Hospital, New York City, from December, 1937, to February 21, 1945.

The serious complications cannot be attributed entirely to intubation. Both cases of ulceration occurred in patients with uremia. In each instance a superficial ulceration was found in the region of the aryepiglottic folds. Perforation occurred in the ileum of a case when, at operation, the adhered ileum was separated from an adherent area which obstructed the intestine. The tube was used as a guide to the obstructed site where the tip had been arrested. The presence of the tube tip was not an apparent factor in the perforation in this case.

Hemorrhage occurred following the introduction of the tube in an elderly patient, with subsequently proven esophageal varices. The presence of cirrhosis of the liver had not been appreciated prior to the passage of the tube. The other two cases of hemorrhage were in patients with an old history of duodenal ulcer. Melena occurred while the tube was *in situ*. The hemorrhage was not severe, and its origin was never proven.

The other five instances of serious complications could not be directly attributed to the tube. The most serious of these was the onset of bilateral vocal cord paralysis in an elderly patient, necessitating a tracheotomy. The tube had been *in situ* for 12 hours before the sudden onset of this complication. Although not proven, the etiology here was suspected to have been a sudden intracranial vascular lesion. The other complications were wound disruptions, postoperative pneumonia, and quite marked dehydration, necessitating parenteral fluids in a patient who would not take fluids by mouth with the tube *in situ*.

#### REFERENCES

- <sup>1</sup> Leigh, Octa C., Jr., and Diefendorf, Richard O.: The Miller-Abbott Tube in Surgery. J. A. M. A., 118, 210-214, January 17, 1942.
- <sup>2</sup> vanBeuren, Frederick T., Jr., and Smith, Beverly C.: Acute Ileus. ANNALS OF SURGERY, 107, No. 3, 321-339, March, 1938.

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# THE SURGICAL SIGNIFICANCE OF AN ANOMALOUS CHOLECYSTOHEPATIC DUCT

CASE REPORTS

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THE SURGICAL SIGNIFICANCE of variations in the anatomy of the biliary system has been the subject of numerous contributions. Concerning the incidence of abnormalities, Flint<sup>1</sup> has shown in a study of 200 consecutive autopsies that there were only 69 cases in which the anatomic pattern of the extrahepatic biliary system (and its associated vascular tree) conformed to the textbook description. An anomaly to which attention has been directed, only infrequently, and which is the subject of this paper is an accessory hepatic duct draining a varying segment of hepatic parenchyma directly into the gallbladder. This biliary pathway, which we shall term the "cholecystohepatic" duct, is found regularly in fish, reptiles and birds (Owen<sup>2</sup>). According to Quain,<sup>3</sup> it is not an unusual finding in some mammals.

Both the occurrence and the surgical significance of the duct in man can be appreciated by a consideration of the embryology of the biliary system.<sup>4</sup> The latter begins with the appearance of the hepatic diverticulum, a saccular pouch from the ventral foregut. The distal end of the pouch is the source of solid cellular strands of tissue from which the glandular portion of the liver is formed. The cellular cords assume, gradually, the pattern of adult hepatic architecture chiefly as the result of invading blood vessels and biliary capillaries. Parallel to, but separate from, the foregoing development is the evolution of the extrahepatic biliary system from a hollow pouch immediately proximal to the developing liver. The distal portion of the pouch becomes the hepatic duct, which sprouts numerous small ducts that enter the substance of the liver. The proximal segment of the pouch (derived from the primitive duodenum) becomes the choledochus. At a variable point between the proximal and distal portions of the pouch is the special offshoot from which the gallbladder and cystic duct are derived. Thus, the gallbladder and hepatic duct are essentially distal segments of the same diverticulum. Presumably because of some error of development small ducts may sprout from the gallbladder as well as the hepatic duct to drain glandular buds of liver tissue. The latter, merging with the fetal liver would, nevertheless, continue to drain into the gallbladder. This appears to be the manner of development of the cholecystohepatic duct which, of necessity, drains a segment of the liver.

It is quite impossible to determine from the literature the incidence of an aberrant duct in man. There are individual case reports, such as an early

one (1913) by Kehr,<sup>5</sup> and one by Schnacher<sup>6</sup> in a review of extrahepatic biliary anomalies. Eisendrath,<sup>7</sup> in a basic paper on anatomic variations of the biliary tree, mentions no instance. The anomaly was not noted apparently in Flint's<sup>1</sup> study, or in 194 dissections by Luge.<sup>8</sup> On the other hand, bile capillaries and often larger bile ducts were found in the gallbladder bed in 15 to 25 per cent of cholecystectomies.<sup>9</sup> Mentzer<sup>10</sup> believes that the duct can be frequently overlooked at operation because of its (usually) insignificant caliber and, also, the reduction of biliary secretion under anesthesia.

Although the incidence of cholecystohepatic ducts remains doubtful or unknown, and the question of postcholecystectomy biliary discharge resulting from severance of such ducts remains open, there can be no doubt as to the hazard of an overlooked severance of a duct of substantial proportions. The excessive loss of bile by external drainage or the likelihood of bile peritonitis from internal drainage need only be mentioned. The obvious management of a small duct which is encountered at cholecystectomy is ligation or sealing by electrocoagulation. When, however, the diameter is large enough to indicate that the duct drains a substantial section of hepatic parenchyma there can be some doubt as to procedure. Thus, Flint<sup>1</sup> believes that intrahepatic collateral biliary circulation is sufficient to prevent liver damage following ligation. He concedes, however, that, in the case of an already damaged liver resulting from prolonged obstruction of the common duct, further insult to a substantial segment of liver by ligation of a large aberrant duct might lead to death. On the other hand, external drainage from an aberrant duct invites local complications, excessive biliary deprivation, and prolonged morbidity. A number of years ago we encountered an aberrant cholecystohepatic duct at cholecystectomy, and employed external drainage. Another case was seen recently, and this time the duct was treated by ligation.

#### CASE REPORTS

**Case 1.**—(A. R. 431484): A 58-year-old female entered the Mt. Sinai Hospital with a four-day history of right upper quadrant abdominal pain and jaundice. Abnormally dark urine was noted but the color of the stools was not observed. The patient had not suffered previous episodes of abdominal pain or icterus, but had had dyspeptic symptoms for a long time. Aside from frequent attacks of bronchial asthma, her past history was not noteworthy.

*Physical Examination:* The patient was obese and moderately icteric. Her abdomen was distended. There was marked tenderness and spasticity in the right upper quadrant where an orange-sized, tender, ballotable mass was palpable, moving with respiration. There was slight fever. *Preoperative Diagnosis:* Common duct obstruction and a distended gallbladder. After preliminary preparation with intravenous glucose solution operation was undertaken.

*Operation:* A right upper abdominal incision disclosed extensive pericholecystic adhesions arising from an enlarged, tensely distended gallbladder. The foramen of Winslow was obliterated by adhesions. Indeed, the diseased gallbladder was quite completely walled-off from the free peritoneal cavity. Cholecystectomy was performed, subserosally, from the fundus downwards. The cystic duct was about three millimeters in diameter, and, after its severance, several cubic centimeters of dark, very viscid bile containing numerous fine crystalline particles, but no stones, escaped from its stump.

Thereafter only thin yellow bile welled-up from the common duct. Exploration of the common duct by palpation and by probe revealed a duct of normal diameter containing no calculi. Since compression and distortion of the duct system by the gallbladder mass appeared capable of producing the icterus of a few days' duration, and exploration was negative (although a stone could of course have been overlooked), the common duct was not opened. A No. 20 F. soft rubber catheter was sewn into the open cystic duct for drainage.

During the course of the dissection of the gallbladder from its bed, an orifice, about two millimeters in diameter, was noticed in the upper portion of the bare area. It was surrounded by a thin but well defined greyish wall. From the mouth of this duct in the gallbladder bed there escaped freely dark, viscid bile, identical with that in the



FIG. 1.—Path. No. P14919: Section of cholecystohepatic duct described in Case 1. Structural details are typical of small bile duct.

gallbladder and cystic duct. Following the escape of this dark fluid, thin yellow bile appeared. A fine probe was passed into the orifice and entered a duct in the liver substance for a distance of two to three centimeters in the direction of the porta hepatis. Sections of the duct were removed for microscopic examination. No other anomaly of the extrahepatic biliary system was noted.

The orifice of the anomalous duct was left open. Rubber dam drains were placed in Morison's pouch and also to the mouth of the aberrant duct, in order to insure external drainage of any biliary leakage that might occur. The wound was then closed in layers.

Microscopic examination revealed the specimen to be a typical bile duct (Fig. 1).

*Postoperative Course:* The immediate postoperative course was uneventful. By the fifth day fever had subsided, icterus had disappeared, the urine was free from bile, and stools were of normal color. The tube in the cystic duct drained thin yellow bile for one week. It was then spontaneously extruded, and some bile discharged into the dressings. The rubber dams were withdrawn several days later.

Eleven days after operation the temperature rose to 102° F. In the absence of any other apparent cause for pyrexia, the fever was assumed to be due to retained infra-hepatic biliary seepage. Accordingly, a tube was placed into the small sinus that

remained, and bile discharged freely. The temperature returned to normal in 36 hours. *It was not until the forty-fifth day after operation that the biliary drainage, which often was profuse, ceased, and was followed by permanent closure of the wound.*

For three weeks after operation the patient complained of anorexia, lassitude, and extreme general asthenia. On several occasions there were brief episodes of marked weakness and vertigo, during which the patient became pale, cold, and clammy, the pulse rapid and thready, and the blood pressure fell to 80/40. There was no associated precordial distress, and no other abnormal physical findings to lead to a diagnosis of pulmonary embolization. The generally debilitated state which existed at the end of three weeks was thought to be due to bile deprivation. The acute episodes were referable either to exaggerations of this state or to pulmonary embolization. Treatment was instituted three weeks after operation. Calcium lactate, yeast, halivar oil, and bile salts were administered, according to the recommendation of Doubilet.<sup>11</sup> Improvement soon followed despite the continuation of biliary discharge; appetite and strength returned; there were no further acute episodes, and the patient was convalescent by the end of the fifth week.

The patient was discharged from the hospital in good condition, seven weeks after operation, with a healed wound. *Follow-up:* There has been no recurrence of symptoms referable to the biliary tract.

**COMMENT:** The precise nature of the anomalous duct discovered at operation can be inferred from the location of its orifice in the liver bed, and the direction of its course. Because of the features which were noted, the structure can be properly termed a cholecystohepatic duct. Its integral relationship to the biliary system is established not only by the flow of bile from its orifice but also by its histologic appearance.

The abnormal appearance of the bile first noticed in the duct, similar to the pathologic fluid in the gallbladder and common duct, is an interesting feature. It suggests a concurrent stasis and infection of the tributary portion of the liver, conceivably of ascending origin from the gallbladder.

In the absence of common duct obstruction, and in accordance with usual experience, drainage of bile from the cystic duct should have ceased within a week or two. The prolonged biliary discharge may, therefore, reasonably be ascribed to leakage from the open cholecystohepatic duct.

The pronounced asthenia after operation, and perhaps the recurrent episodes of mild shock, can be attributed to prolonged continuous drainage of bile, with consequent loss of electrolytes and faulty vitamin absorption. This etiologic relationship is suggested by the prompt response to a regimen of high salt and vitamin content. Biliary deprivation due to leakage from a severed anomalous duct may, therefore, be of serious import *per se*, aside from possible intra-abdominal complications that might ensue.

Ligation of the duct was discussed at the time of operation. The decision to leave the duct open was made because its caliber was relatively large, the amount of tributary hepatic tissue was in doubt, and the functional state of the liver in this icteric patient was unknown. In retrospect, it can be assumed that ligation would have been safe, and that the postoperative complications would not have ensued.

**Case 2.**—(C. F. 462649): A 63-year-old female entered the Mt. Sinai Hospital with a history of recurrent right upper quadrant abdominal pain for 40 years. These

attacks had become more frequent during the past two months, and, two weeks before admission, for the first time, were associated with chills and fever for several days. At no time had jaundice been noted. The patient's past history was otherwise not contributory.

*Physical Examination:* The patient was obese. There was no evidence of icterus. Admission temperature was 100.6° F.; blood pressure 130/86. The abdomen was obese and pendulous. Tenderness and spasticity were present over the right upper quadrant, and an enlarged gallbladder was palpable, moving with respiration. Examination disclosed

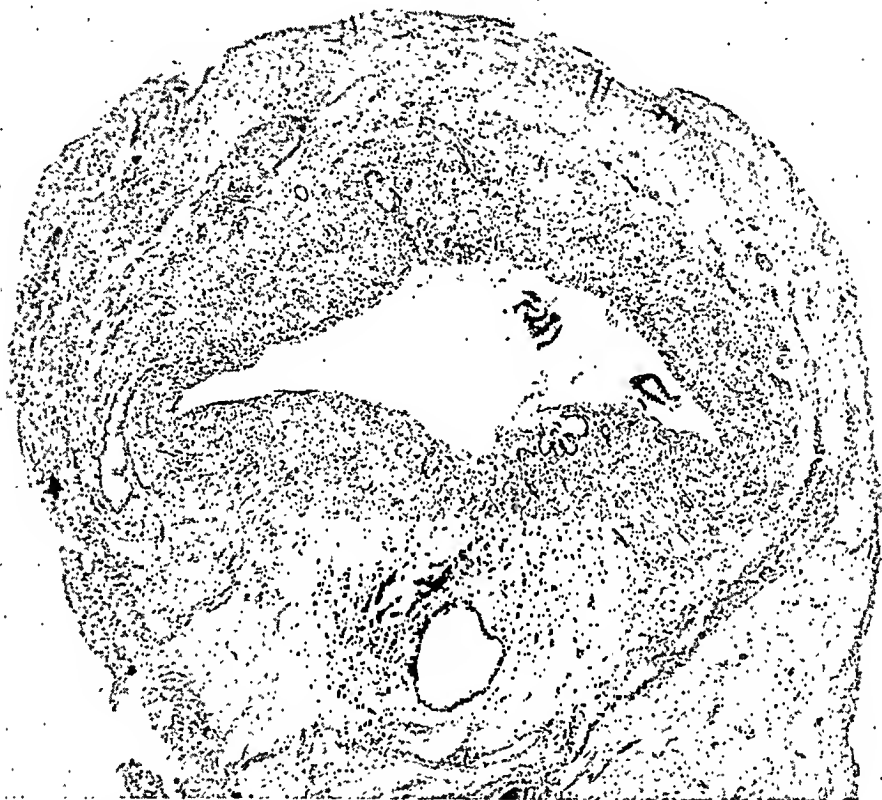


FIG. 2.—Path No. P19088: Section of cholecystohepatic duct described in Case 2.

no other abnormalities. *Preoperative Diagnosis:* Hydrops of the gallbladder. After suitable preparation operation was undertaken.

*Operation:* A transverse right upper quadrant incision disclosed an enlarged, chronically inflamed gallbladder containing numerous stones. There were many dense adhesions including the cystic and common ducts. A subserosal dissection of the gallbladder was carried out. In the course of the separation of the gallbladder from the liver bed, a sudden escape of bile was noted. Examination of the under surface of the liver, at this point, showed the biliary leakage to occur from the lumen of a duct apparently running into the gallbladder from the liver. A section of the walls of this orifice was taken for microscopic study, and the lumen was then closed with a suture.

Microscopic examination of the aberrant duct section revealed a typical bile duct (Fig. 2).

*Postoperative Course:* The postoperative course was uneventful. Sutures and drains were removed on the eighth postoperative day. The patient was discharged from the hospital four days later, afebrile, with wound healing well. *Follow-up:* There have been no symptoms referable to the biliary tract.

COMMENT: From the gross appearance of the aberrant duct leaking bile in the liver bed, and its microscopic appearance, there can be no doubt of its nature. The similarity in size and location of this duct with that described in Case 1 suggested the probability of a complicated convalescence, unless ligation was performed. In the absence of evident icterus, to suggest hepatic dysfunction, no hesitancy was felt in doing so. Closure was, therefore, done—and an uneventful postoperative course ensued.

#### CONCLUSIONS

The existence and surgical significance of an anomalous duct between liver and gallbladder (to which we have attached the term "cholecystohepatic" duct) can be understood best by a consideration of its embryology.

Although a duct of substantial proportions probably is a rare anomaly, its presence at the operation of cholecystectomy creates an important problem.

Since the duct is inevitably severed during cholecystectomy, its nonrecognition, because of uncontrolled leakage of bile, may lead to peritonitis, localized infection, or the symptoms of prolonged biliary deprivation.

Ligation of the duct is probably a safe procedure in most cases. In the presence of stasis and infection within the segment of liver drained by the duct, drainage and not ligation may be indicated despite the complications which are invited.

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# COMPLICATIONS OF INTRA-OSSEOUS THERAPY

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IN 1940, WHEN the technic for infusing blood or other fluids into the circulation *via* the bone marrow was discussed, the following points were stressed: (a) The method is indicated only when intravenous injections or infusions are needed and the peripheral veins are not available for one reason or another (poor development; delirious or uncoöperative patients; extensive burns; shock). (b) The operator should familiarize himself with the anatomic landmarks in adults (sternum) and infants (tibia and femur), and practice the technical steps on the cadaver before attempting to carry out the procedure in a patient. (c) No irritating substances should be introduced by this route. (d) In the presence of extensive infection, with or without bacteriemia, the use of this route is not advisable except for the introduction of bacteriostatic drugs (sulfonamides, penicillin).<sup>1, 2, 3</sup>

There has been wide application of this method and the reports thus far published have, on the whole, been favorable.<sup>4-12</sup> The feeling may grow, however, that infusion by this method may be undertaken by any one, without previous training and in disregard of the points enumerated above. Lest this happen, attention is hereby drawn to certain serious complications which have resulted from trials at the performance of this technic.

The outstanding example of the consequences of flagrant disregard of simple precautions is that reported by Ravitch,<sup>20</sup> in September, 1943: Seventy-five cubic centimeters of *seven-day-old blood*, removed from a flask *opened two days previously*, were given in the *sternum of an eight-month-old infant*. The child developed a mediastinal abscess requiring drainage, which was followed by recovery. In October, 1941, the anatomic features of the bone marrow in the sternum, femur and tibia of infants were reviewed, and attention was drawn to the fact that in infants under three years of age, the sternum should not be used for this purpose because of its small size and somewhat irregular distribution of its marrow deposits.<sup>2</sup> Use of either femur or tibia was recommended in such patients.

Papper<sup>7</sup> has recorded a death presumably resulting from the administration of 5 per cent glucose solution *via* the marrow of the corpus sterni in a 20-year-old woman, with acute thrombopenic purpura. The infusion needle was inserted into the sternum while a splenectomy was in progress and, because of the necessity of not interfering with the operative field, the needle was pointed caudad. A small amount of marrow was obtained before the

infusion was carried out. The patient died 12 hours postoperatively, and postmortem aspiration of the pleural spaces yielded about two liters of fluid containing glucose in almost 5 per cent concentration. Autopsy was not completed. Whether the insertion of the needle in the caudad direction affected the technic is uncertain.

Elsewhere<sup>21</sup> we have described a similar complication which, however, did not end fatally. In attempting to enter the sternal marrow, two orifices had been made. At the first trial the posterior plate of the sternum had apparently been penetrated. The needle had been withdrawn and the second insertion made, slightly below the first one, but in the same segment of bone. Some of the fluid infused through the point of the second insertion, apparently found its way into the chest through the orifice made on the posterior plate during the first trial (Fig. 6).

Two instances of supposed osteomyelitis have been called to our attention, following attempts at infusion *via* the tibial marrow. In both instances, in spite of the fact that no marrow was removed, an attempt had been made to inject blood forcibly. Each patient received between two and five cubic centimeters of blood. Roentgenograms disclosed elevation of the periosteum and some resorption of the nearby bone in each patient. It is likely that in each of these instances the blood was injected not into the marrow cavity but subperiosteally. The bone resorption changes usually demonstrated roentgenologically<sup>4</sup> in these and similar instances probably result from pressure necrosis rather than from true osteomyelitis. A severe osteomyelitis did follow the use of this route in an infant with *Staphylococcus aureus* abscesses throughout the body, and a probable bacteriemia (ref. 22, footnote). Blood had been injected through the tibia during the height of the acute septic process, not far from an area where there were several subcutaneous abscesses.

Behr<sup>23</sup> gave 60 infusions to infants, and had two complications. In one child the needle-guard pressed against the leg and caused necrosis of the skin. In another child the needle was left in place for about three days, resulting in leakage of fluid around the needle into the subcutaneous space. An osteomyelitis developed which cleared up after surgical treatment. Maintenance of a needle in the bone of infants for prolonged periods of time (over 12 hours) seems inadvisable. It is perhaps preferable to use another bone if the infusion must be repeated every other day. The devices introduced by Gimson,<sup>11</sup> and Behr,<sup>23</sup> to prevent undue motion of the infant's leg while the infusion is in progress and to guard against a too deep penetration of the needle into the bone, are useful additions to the technic.

Meola<sup>12</sup> describes the occurrence of black discoloration of the foot and leg of a six-week-old female child, within one-half hour after 50 cc. of plasma and 50 cc. of 10 per cent glucose solution had been given without difficulty into the right tibia. The discoloration extended one-third of the way up the leg to a point two inches distal to the site of the needle puncture, and was followed by loss of the great and middle toes on the involved foot. The cause

of the reaction was not clear; it was felt that arterial thrombosis might have occurred. Dickins and Richmond<sup>24</sup> have recently reported gangrene of toes associated with a "thrombophlebitis" in a premature infant, and possibly related to the hypodermic injection of a vitamin K preparation into the thigh. This incident, in which the injection was not intra-osseous, and not so intended, necessitated disarticulation of all the metatarsal bones in the involved foot.

The following complication arose after infusions into the sternum of an adult: A 25-year-old woman was hospitalized because of intestinal obstruction. She had had diabetes mellitus for 14 years, and had had her right kidney



FIG. 1.—Appearance of lesion before incision and drainage.

removed in April, 1943, because of abscesses and pyelonephritis. She later became pregnant and, because of poor renal function and almost unmanageable diabetes, a therapeutic abortion and fundectomy were performed in March, 1944. In June, 1944, she suffered an attack of amebic colitis which responded promptly to therapy.

The intestinal obstruction failed to be relieved by conservative therapy and celiotomy was performed on August 4, 1944, revealing organic, sigmoidal obstruction due to old diffuse pelvic inflammation, with matting together of intestinal loops. The involved loops were freed, cecostomy was performed, and the abdomen closed. Postoperatively, it was difficult to control her fluid balance and diabetes. Feeding during the first few days had to be entirely parenteral. Her veins were extremely small and efforts were made to preserve the few which were available as sources of blood samples needed for biochemical determinations. She received infusions of blood, plasma, 0.85 per cent NaCl, and 10 per cent glucose in saline by the intravenous and intramedullary routes. On August 4 and 5, 1944, the patient received 1,500 cc. of 10 per cent dextrose, 500 cc. of whole blood and 500 cc. of 0.85 per cent NaCl *via* the

marrow of the corpus sterni. On August 12, 1944, while receiving whole blood *via* the marrow of the manubrium, the needle worked loose and before its malposition was discovered, a fairly large amount of blood had escaped into the subcutaneous tissues of the upper anterior chest wall. Her post-operative course was further complicated by wound disruption and a fecal fistula. The wound was resutured and the fistula gradually closed. Because

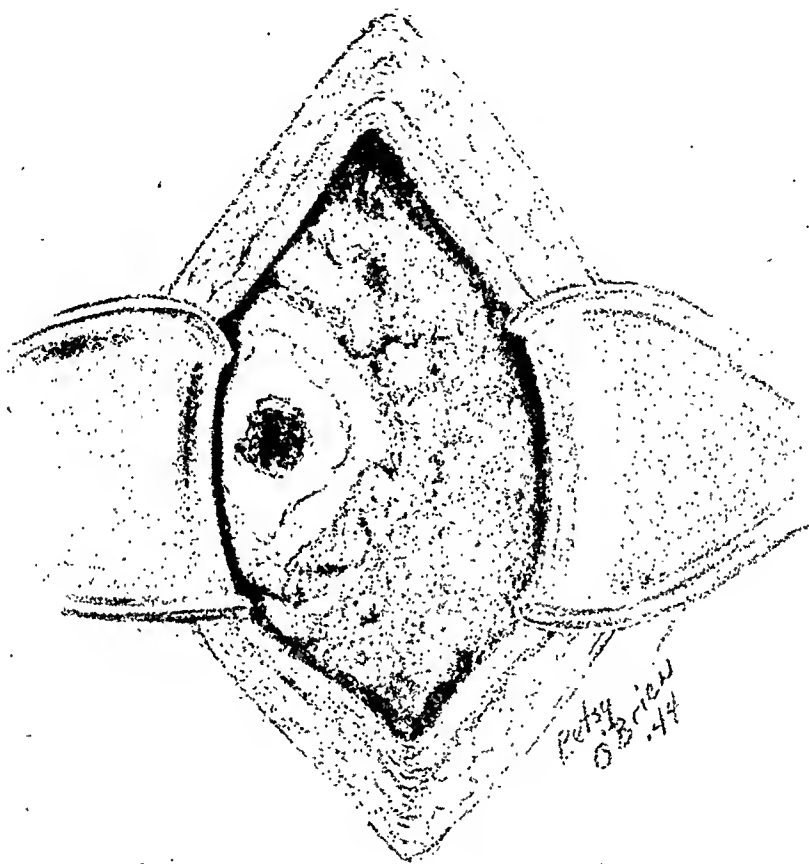


FIG. 2.—Operative exposure of the site of the infusion into the sternum.

of the deposition of blood in the subcutaneous tissues, the area over the manubrium sterni was diffusely swollen and discolored. This reaction gradually decreased, leaving a 4-cm. zone of induration, which was elevated 0.5 cm. above the surrounding skin. This area remained slightly tender, and at irregular intervals the patient complained of pain in her right shoulder top. Clinical and roentgenologic search failed to disclose any intrathoracic or subphrenic lesion.

The patient was discharged, September 30, 1944, and five days later the area over the manubrium gradually began to increase in size and in tenderness. At the same time the dull pain in her right shoulder grew worse. The swollen zone pointed and opened spontaneously, draining thick yellow pus. She was treated by her local physician and returned to the clinic for reexamination one month later. At that time the two sinuses were draining purulent

material and the surrounding zone was slightly swollen and tender (Fig. 1). Culture of the exudate yielded *Staphylococcus albus*. Roentgenologic examination of the sternum disclosed slight irregularity about the right lateral margin of the manubrium near the sternoclavicular articulation, with localized areas of decalcification and irregularity of the cortex, due probably to osteomyelitis.

On November 9, 1944, under cyclopropane-oxygen anesthesia, a vertical incision was made through the sinus tracts and carried down to the manubrium sterni. A core of soft granulation tissue extended from the skin sinuses down to a 4-mm. opening in the anterior sternal plate (Fig. 2). The opening was enlarged, exposing an area of seminecrotic tissue, which was curetted away. The entire cavity was packed with iodoform gauze. Tissue removed at operation showed inflammatory and fibrotic reactions, with a few bony spicules scattered through the sections. When discharged from the hospital, November 15, 1944, the cavity was clean and draining little. She is being cared for by her family doctor and his last communication states that the wound was healing well.

The advanced deterioration of the patient's metabolic status, probably contributed somewhat to the local changes at the point of the infusion. The same reason, however, made it imperative, originally, to use the intra-osseous route, since peripheral veins were unavailable. In this group of patients one must, therefore, take special precautions to avoid mishaps such as dislodgement of the needle, long maintenance of the needle in the bone, and possibility of surface contamination. A similar complication has been recorded by Jimenez Pinto.<sup>4</sup>

COMMENT: A distorted impression of the risks of intra-osseous therapy is certain to result from isolated consideration of the above-mentioned complications. A more balanced view is obtained if the complications are viewed against the background of those known to have followed other types of parenteral therapy. The intramedullary route shares with other parenteral routes the fundamental risks and complications surrounding the introduction of a hollow needle into the body. In addition, it has a few risks of its own. In many respects, the present status of intramedullary injections is analogous to that of intravenous, intramuscular and subcutaneous injections during the second and third decades of the present century. The medical literature of that period contains numerous references to the complications and difficulties experienced at a time when certain parenteral routes were becoming popular, but were still under trial. No figures are available for the average incidence of complications which occurred either during or after such injection therapy and whether they resulted from action of the substance injected, faulty technic, or both. Local suppuration as well as aseptic necrosis following parenteral injection (intravenous, intramuscular or subcutaneous) was reported by various authors.<sup>25-28</sup> Gas gangrene following injections was discussed by Junghanns,<sup>29</sup> and Harney.<sup>30</sup> The latter author reported 86 instances of gas gangrene following various parenteral injections; the mortality

for this group was 88 per cent. Reports of venous thrombosis and thrombophlebitis following injection therapy, leading at times to fatal pulmonary emboli and pulmonary infarctions, were not uncommon.<sup>31-36</sup> Systemic infection, including septicemia and metastatic osteomyelitis, was reported by Gants.<sup>32</sup> Various types of nerve injury followed injection therapy.<sup>37-40</sup> Payenneville and Castagnol<sup>41</sup> recorded an instance of intramuscular injection in the gluteal region producing gangrenous changes and destruction of the

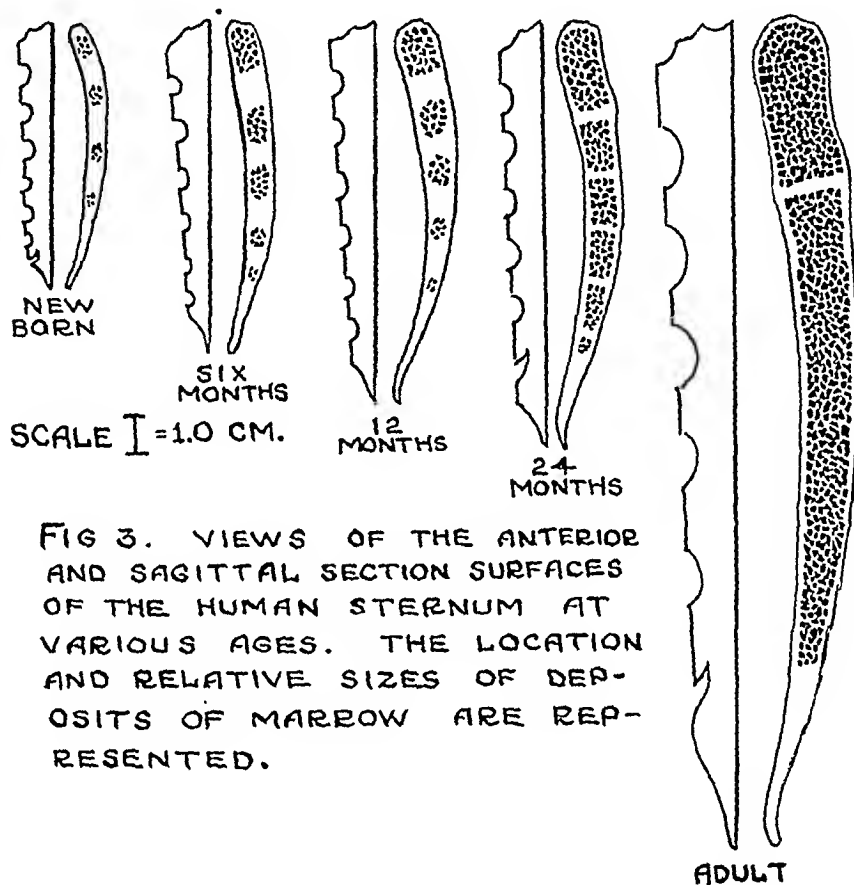


FIG 3. VIEWS OF THE ANTERIOR AND SAGITTAL SECTION SURFACES OF THE HUMAN STERNUM AT VARIOUS AGES. THE LOCATION AND RELATIVE SIZES OF DEPOSITS OF MARROW ARE REPRESENTED.

FIG. 3.—Diagrammatic representation of the relative sizes of human sternal plates, showing the development of marrow deposits.

anastomosis of the gluteal and internal pudendal arteries, with necrosis and gangrene of the rectum, bladder, genitalia and thigh. Arterial embolism has followed the intramuscular injection of iodobismotol into the buttock.<sup>42</sup> Complications, both local and general, have followed intra-arterial injections for roentgenographic visualization of the vessels.<sup>43</sup>

Therefore, when assessing the dangers of intra-osséous therapy, one must keep in mind the risks inherent in the parenteral administration of any substance, in addition to those that may be peculiar to intra-osseous therapy. Our own experience with over 400 intra-osseous infusions, and the experience of others,<sup>1-23</sup> have not caused us to modify our feeling that, if the method is employed only when indicated, by those who are familiar with the technic, and who observe the known contraindications, the risks involved do not appear to be any greater than those carried by other forms of parenteral therapy.

## SUGGESTIONS FOR THE PREVENTION OF COMPLICATIONS

Aside from complications caused by bacterial contamination, most difficulties seem to originate from failure to consider anatomic details, and how they govern the fate of fluid injected into various bone marrow deposits.

*The Sternum in Infants.*—At birth, the sternum is a cartilaginous plate 5 to 7 cm. long, from 1.0 to 1.5 cm. broad, and from 1.0 to 3.0 mm. thick. There are usually three deposits of marrow in its substance, varying in diameter from 5.0 mm. in the manubrium (which is the most constant one in size and location) down to 1 or 2 mm. in the lower part of the body (Fig. 3).

As the infant grows, these deposits of marrow increase in size. By the age of 24 months the original island of marrow in the manubrium occupies all of that part of the sternum save for a soft, partly ossified, but mainly cartilaginous cortex, about 0.5 mm. in thickness. It is important to note, that, in the specimens so far examined, in no instance did the marrow in the manubrium communicate with that in the corpus sterni (Fig. 3). Any attempt to infuse fluid into the sternal marrow of an infant less than 24 months old is courting almost certain failure or disaster, for: (a) the marrow islands are small; (b) they are irregular in location; (c) the sternal plate is soft and only 2 or 3 mm. thick, making entrance into the mediastinum, highly probable; and (d) even if the needle tip fortuitously rested in a marrow deposit, its small size would prevent its transporting any appreciable amount of fluid. Theoretically, at the age of 24 months, one might infuse fluid *via* the manubrial marrow without complication if the operator were unusually dexterous, but, because of the above-mentioned reasons, injections in any part of the sternum in a child less than 36 months old should never be attempted.

*The Tibia and Femur of Infants.*—The lower end of the femur and the upper end of the tibia are the sites of election for the infusion of fluid in infants up to four, and probably up to five years of age. The marrow deposit in the distal end of the femur is approximately 1.8 cm. broad at its widest point, and 6 to 10 mm. deep, while that in the proximal tibia is usually 6 to 8 mm. in any diameter. At birth, the distal 1.0 to 1.5 cm. of the femur and the proximal 1.0 to 1.5 cm. of the tibia are cartilaginous, and each contains a single center of ossification. These centers appear at about the time of birth, and join their respective shafts at about the twentieth year.

In infancy the patella is cartilaginous and ossifies from a single center, which appears at the third year and is completely ossified at puberty. When inserting a needle into the marrow cavity of the lower end of the femur in an infant, the operator must avoid the patella, and he must recall that the needle will traverse the upper extension of the synovial cavity beneath the quadriceps tendon anterior to the femur (Fig. 4). Careless technic may result in injury to the epiphyseal line or causing fluid to enter the knee joint.

The marrow cavity of the upper end of the tibia must be entered, not

directly anteriorly, but on the anteromedial surface of the bone, with the needle pointed away from the knee joint, in order to avoid injury to the epiphyseal line, which lies 1 to 1.5 cm. distal to the distal edge of the patella when the knee joint is extended (Fig. 4).

When inserting a needle into either tibia or femur, it is possible to drive the point through both anterior and posterior cortical plates, with resulting deposition of fluid into the popliteal space. This area is enclosed by fascia

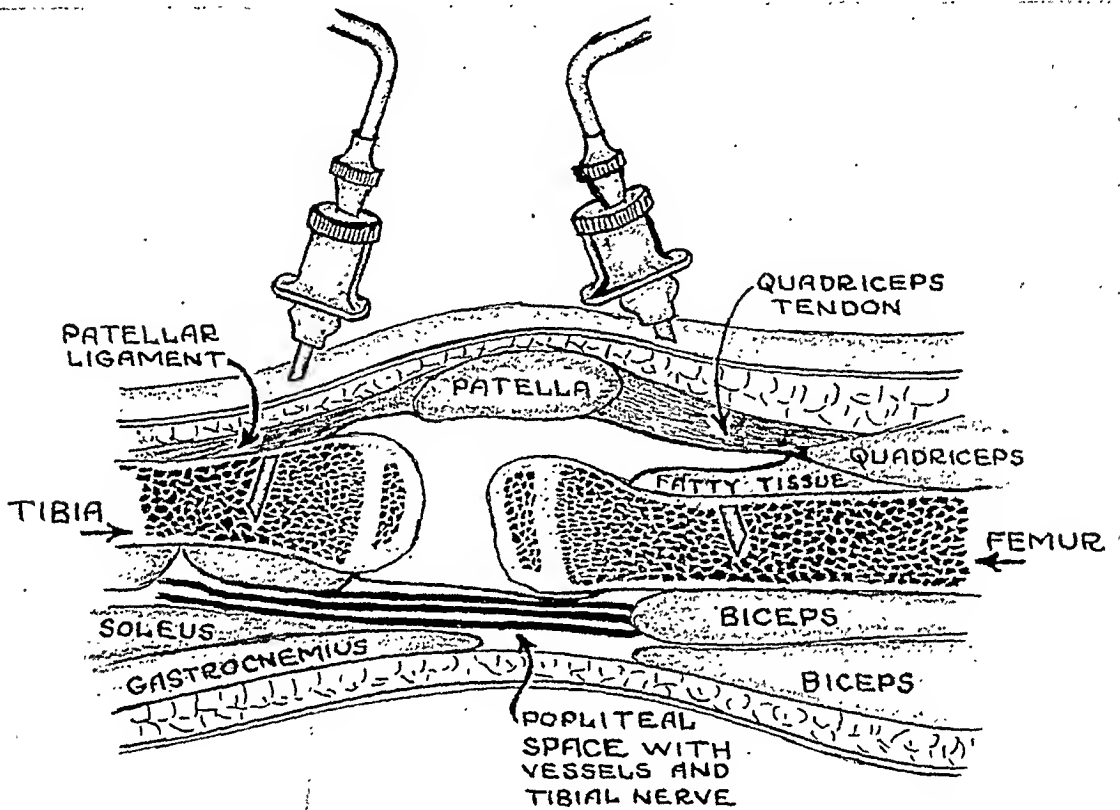


FIG. 4.—Diagram of a longitudinal section of the knee joint area in a full-term, newborn infant, showing the important anatomic relations and the correct position of needles for infusion. In the diagram the size of the joint cavity proper is purposely exaggerated.

and sufficient pressure may be built up within it (particularly if the substance is injected rather than administered by gravity flow) that the popliteal vessels may be shut off and the tibial nerve damaged. The needle-guard and precautions advocated by Gimson<sup>11</sup> should help in preventing this mishap.

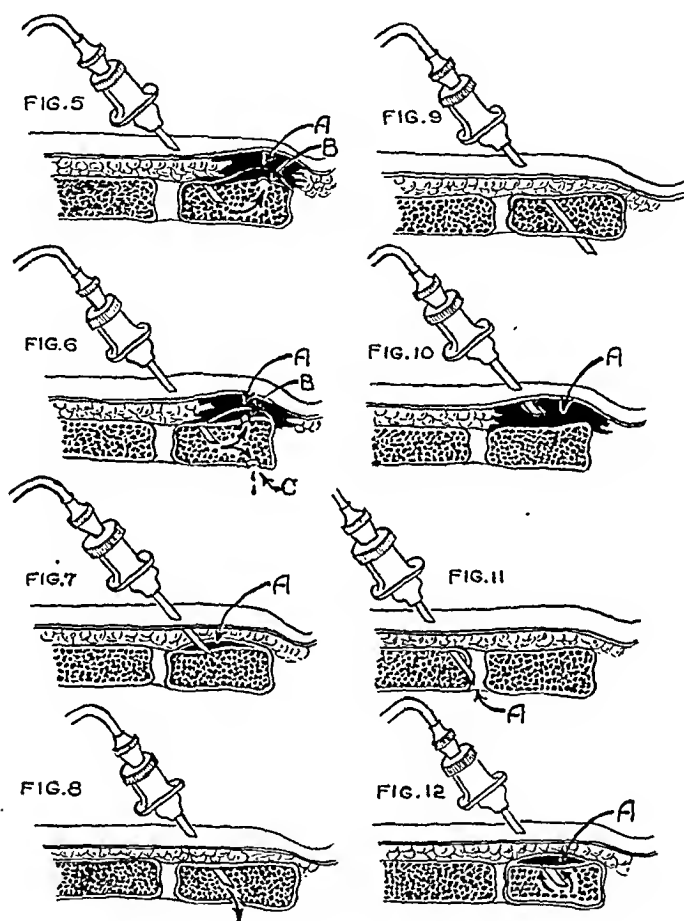
The red marrow in the tibia and femur begins to change into fatty marrow between the fifth and seventh year. Theoretically, therefore, the tibia or femur should not be used for infusion after the age of five.

*The Adult Sternum.*—If a needle is inserted into either the manubrium or the corpus sterni and, for any reason, the infusion attempt is unsuccessful, under no circumstances should the needle be removed and reinserted close by the first puncture site within 12 hours. This is most important when any suspicion exists that the posterior plate might have been punctured. If this precaution is overlooked and a second puncture is made soon after, near to the preceding orifice, part of the fluid infused *via* the second orifice will



leak out through the first one, resulting in a collection of fluid either beneath the skin, beneath the periosteum (Figs. 5 and 6-A, B) or in the mediastinum (Fig. 6-C).

A similar word of caution applies to infusing fluid through a needle which has been deeply inserted, and then partially withdrawn after the operator was unable to aspirate marrow. This maneuver may leave a hole in the posterior surface of the sternum, and fluid infused will leak into the



FIGS. 5 to 12, incl.—Mechanism of complications resulting from various errors in the technic of inserting a needle into the sternal marrow. Each drawing represents a sagittal section of the manubrium and upper portion of the body of the sternum of adult man.

mediastinal space (Fig. 8). If the needle tip perforates the posterior sternal plate the operator will not be able to aspirate marrow (Fig. 9).

When, for any reason, a needle is withdrawn from one compartment of the sternum, and must be reinserted soon thereafter, it should be placed in a separate portion of the sternum. Thus, if the first attempt was in the manubrium, the second should be made in the corpus, or *vice versa*. It is probably safe, when the need is imperative, to make more than one puncture in the body of the sternum within a short time (two to three hours), provided the orifices are at least six or seven centimeters apart.

## INTRA-OSSEOUS THERAPY

If sufficient time has elapsed for previously made orifices to become occluded by firm clots, a second puncture can apparently be made nearby with safety. It is assumed that 12 hours is sufficient time for a firm clot to form unless a disorder of the blood is present. This time-interval will also vary with the amount of pressure applied to the fluid infused through the second orifice.

If a long-bevelled needle is used, it is possible for some of the infused fluid to enter the marrow cavity and some to leak out subperiosteally (Fig. 7). A similar difficulty arises if the needle works loose, and fluid leaks out around

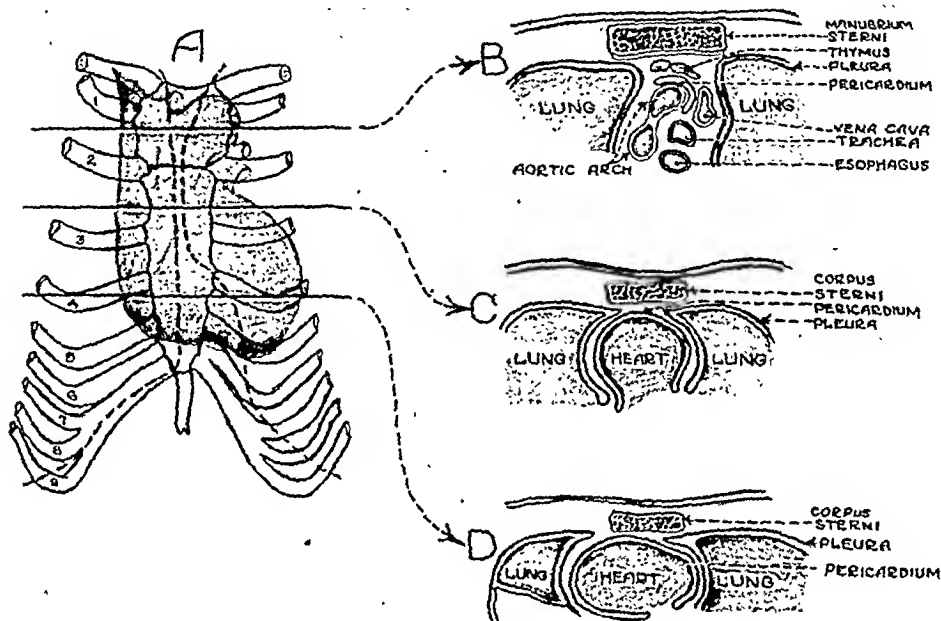


FIG. 13.—Diagrammatic representation of cross-sections of the sternum and thoracic viscera made at the three levels at which intra-osseous infusions are usually given. In "A" the solid dark shadow represents the outline of the heart and great vessels; the solid black lines represent the outlines of the sternum and adjacent parts of the clavicles and costal cartilages; the dotted lines represent the reflections of the pleura. From the cross-section diagrams, "B", "C", and "D", it may be seen how faulty technic might result in damage to the intrathoracic viscera.

it (Fig. 12). A needle may become dislodged completely from the bone, and a quantity of fluid may be deposited in the subcutaneous tissues (Fig. 10). This occurred in the patient whose case was related above. If a needle is inserted too high in the corpus sterni, or at too oblique an angle, its point may come to rest in the cartilage of the superior intersternal articulation. In such an instance, no marrow would be aspirated, and, therefore, an infusion should not be attempted (Fig. 11).

From a consideration of the cross-sectional anatomy of the sternum and thoracic viscera, as diagrammed in Figure 13, it is obvious that faulty technic may result in instillation of fluid into the pleural, pericardial or mediastinal spaces, with sequelae depending on the amount and type of fluid infused.

### SUMMARY

To avoid needless complications, the intra-osseous route for the infusion of fluids should be employed only when indicated, by those acquainted with

the technic and the existing contraindications. The risks involved in intraosseous therapy do not appear to be any greater than those inherent in other forms of parenteral therapy. A complication is reported following infusion *via* the sternal marrow of a diabetic. The relevant anatomy, as well as certain actual and possible technical mishaps, are reviewed.

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# COMA DURING AND FOLLOWING SPINAL ANESTHESIA

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IT HAS LONG BEEN KNOWN that severe anoxemia produces damage to the brain tissues, the cortical areas being the most vulnerable. Caine<sup>1</sup> first suggested the possibility of cerebral damage as the cause of death following nitrous oxide-oxygen anesthesia. Courville<sup>2</sup>, in his classical report, showed that the pathologic changes in the brain in deaths following nitrous oxide anesthesia were similar to those found after asphyxia, and, thus, definitely linked the etiology to anoxemia.

Many other investigators have shown this to be true in methods of anesthesia other than that with nitrous oxide. Steegman<sup>3</sup> reported four cases of prolonged anoxemia, two following nitrous oxide, one after avertin, and one with cyclopropane. The clinical syndrome in all cases was characterized by coma or stupor interrupted by screaming, maniacal delirium, hyperkinetic restless motor symptoms, visual disturbances and autonomic signs: variability in the pulse and blood pressure. Murphy<sup>4</sup> reported a case of severe neuropsychiatric disability following partial exsanguination and shock from blood loss following an attempted suicide. There was no anesthetic involved in this case. Schnedorf<sup>5</sup> *et al.*, report two cases, one, a man who went into shock during an extensive operative procedure under spinal anesthesia, lapsed into coma, and remained there until death. The other was a child who received open-drop ether anesthesia for approximately one hour and then did not react, but instead showed signs of brain damage and died. Both these cases, on autopsy, showed the cortical degeneration typical of anoxemia.

It has been demonstrated experimentally and seen clinically that the extent of brain damage is directly proportional to the duration and severity of the anoxemia<sup>6, 7, 8</sup>. In this report, anoxia of sufficient extent to produce coma during spinal anesthesia will be considered. In all these cases collapse and coma occurred, but prompt intervention made possible complete recovery of the patient. The relief of the anoxia prevented the occurrence of irreversible changes in the brain.

## ETIOLOGY

The etiology of anoxia in spinal anesthesia is varied. Three chief factors are involved. If the anesthesia reaches too high a level, the resultant paralysis of the intercostal muscles causes a decrease in the vital capacity. The impaired respiratory excursions lead to decreased oxygenation, which, if not counteracted with inhalations of high concentrations of oxygen, leads to fatal anoxia. If the level of anesthesia reaches inordinate heights, it may involve the diaphragm, in which case respirations must be maintained by artificial means such as intermittent manual compression of the rebreathing bag of an anesthesia machine or artificial respiration by any of the accepted methods

of manual compression of the chest, such as the Schaeffer. The former is the better since efficient ventilation with high oxygen concentrations can be attained.

Secondly, the drop in blood pressure associated with any of the factors in an operative procedure, such as hemorrhage, reflexes from traction on the mesentery, or the vasodilatation of the spinal anesthesia itself, if allowed to persist, leads to surgical shock. The hypotension results in severe anoxia of the cerebral centers. When the respiratory center is subjected to acute anoxemia it may be markedly depressed, resulting in apnea of central origin.

Third, mechanical factors may cause anoxia from impaired respiratory excursions. The use of abdominal packs against the diaphragm, retractors against the costal margins, assistants leaning on the chest, steep Trendelenburg position, and kidney or gallbladder bars, all tend to inhibit respiratory excursions and may lead to anoxic anoxia intense enough to precipitate a collapse.

Anoxia, when severe, produces unconsciousness for varying periods of time, and the effects may be divided into four groups, depending upon the severity of the anoxia and the changes it produces. When remedied it may resemble syncope, with rapid recovery of consciousness. In cases where the anoxia has persisted for a slightly longer time, the patient may remain unconscious for periods up to 24 or 36 hours, but recover without sequelae. After sublethal periods of anoxia, the patient eventually recovers consciousness and lives, but shows signs of permanent brain damage. In the final group, the patient either dies on the operating table or remains comatose in the postoperative period, with signs of cortical degeneration until death occurs in several days.

The following case reports illustrate several of the etiologic factors and the treatment of the anoxia when it occurs.

#### CASE REPORTS

**Case 1.**—J. B., a well-developed, moderately obese, 50-year-old, white female, was admitted with acute appendicitis. Premedication of morphine sulphate gr.  $\frac{1}{4}$ , and atropine sulphate gr.  $\frac{1}{150}$  was given subcutaneously 15 minutes before the anesthetic. Ephedrine sulphate, gr.  $\frac{3}{4}$  was given hypodermically five minutes before the spinal tap.

Lumbar puncture was performed in the third interspace, with the patient in the left lateral position. Two cubic centimeters of spinal fluid were withdrawn and used to dissolve 100 mg. of procaine hydrochloride, to which was then added 1 cc. (10 mg.) of pontocaine, and the mixture injected slowly. The patient was turned upon her back in 5° Trendelenburg, and the operative procedure was started five minutes later. The blood pressure was still at the preoperative level of 130/80. When the appendix was being removed ten minutes later, the patient complained that she could not catch her breath and then rapidly became cyanotic. At this time her pulse was rapid, and the blood pressure 170/110. The patient ceased voluntary respirations several minutes later, and 100% oxygen was administered by manual compression of the rebreathing bag of the anesthesia machine. The patient was now unconscious and did not respond to any stimuli. Her blood pressure rose to 220/120, and the operation was rapidly concluded. Intravenous medication of coramine, Gm. 0.25 and caffeine sodium benzoate gr. 5 were given while the patient was being maintained with artificial respiration. Spontaneous

respirations were resumed after about five minutes of artificial respiration but were diaphragmatic and very shallow and were reinforced by manual pressure on the rebreathing bag for about 30 minutes.

In the hour immediately following the operation, the blood pressure gradually fell from its high of 220/120 to its approximate normal of 120/70, and remained there. The patient was still comatose, not responding to any stimulation. Bilateral positive Babinski signs were present.

After two hours the oxygen was discontinued since the patient's color was good and the pulse and blood pressure well within normal limits. Since the patient was still comatose, a mixture of 95% oxygen and 5% carbon dioxide, was given every hour for ten minutes for the first 20 hours in the postoperative period, and her position in bed changed every two hours. The first response to stimuli was obtained 16 hours after the patient had lapsed into coma, and she finally spoke coherently, knew who and where she was, 30 hours after operation. She then had an uneventful and uncomplicated recovery. No sequelae remained.

**COMMENT:** The cause of the collapse in this case apparently was a spread of the anesthesia to too high a level, first involving the intercostal muscles and then reducing the vital capacity, and then involving the phrenic nerve causing paralysis of the diaphragm. The resultant apnea produced anoxic anoxia which was combated by ventilation with 100 per cent oxygen by artificial respiration. The pulse and blood pressure remained strong and responded to the anoxia by trying to supply more blood to the brain as evidenced by the increased pulse rate and rise in blood pressure. If the anoxia had not been relieved, the blood pressure would have subsequently fallen before the death of the patient.

**Case 2.**—T. D., a thin, 52-year-old, white female, in poor general condition, was admitted with an abdominal abscess, which was drained under general anesthesia, with cyclopropane, oxygen and ether. Two weeks later she showed signs of intestinal obstruction, and a barium enema revealed a growth in the rectosigmoid region. A cecostomy was performed under spinal anesthesia, using 100 mg. of monacaine formate in 2 cc. of spinal fluid injected into the third lumbar interspace. The patient tolerated the procedure well, with no change in condition.

After she was given strong supportive treatment and her general condition improved, she was scheduled for resection of the rectosigmoid. Premedication was seconal gr. 3 *per os* at 6:30 A.M. and morphine sulphate gr. 1/6 and atropine sulphate gr. 1/150 subcutaneously at 7:30 A.M. Continuous spinal anesthesia was started at 8:25 A.M., and the incision made at 8:35 A.M. She was given 3 mg. of neosynephrin subcutaneously at 8:20, and an infusion started at 8:30. During the operative procedure she received 1,000 cc. of saline and 500 cc. of whole blood. The anesthetic agent was procaine hydrochloride injected into the third lumbar interspace, with fractional doses of 120 mg. first dose and 60 mg. each succeeding dose for a total of 480 mg. The operation proceeded nicely, and the patient's condition remained fairly good, the pulse varying from 72 to 88, and the blood pressure after falling from 120/70 to 80/56 in the first half hour remained there throughout the procedure.

At 12:10 P.M. the blood pressure fell to 65/46, and coramine Gm. 1.25 was given intravenously. At 12:15, while the abdomen was being closed, the patient went into severe shock. Blood pressure, pulse and respirations were absent; the skin was cold and clammy. The patient had been receiving a 50% mixture of nitrous oxide and oxygen throughout the operative procedure, and now this was changed to 100% oxygen and given by artificial respiration, using the rebreathing bag of the anesthesia machine. The

following stimulants were given intravenously into the tubing of the infusion: ephedrine sulphate gr.  $\frac{3}{8}$ , caffeine sodium benzoate gr. 7.5, metrazol gr. 3. At 12:30 P.M. the pulse had returned and was 104. The blood pressure was 100/76. At 12:45 the blood pressure was 140/100, pulse 132. The operation was concluded, and the patient returned to her room.

The patient had been awake and able to respond throughout the operative procedure until the time she went into shock. At this time her respirations ceased along with the disappearance of the pulse and blood pressure. She remained unconscious although the respirations were resumed in eight minutes, and she did not respond when returned to the ward, where she was given 500 cc. of plasma and oxygen by B.L.B. mask. Her breathing was stertorous and general condition poor. At 1 o'clock she had a mild convulsive seizure which started in the face and arms and spread throughout the body. These seizures occurred intermittently for about an hour, each lasting for several minutes. Her eyes were staring, glassy; there was no corneal reflex. Her blood pressure rose during the afternoon to 156/60 at 5 o'clock. She vomited once at about 5:30, but still did not respond. At 6:00 o'clock the blood pressure had risen to 160/86, breathing was easier, and the patient was sleeping fairly quietly. At 6:30 she had another convulsive seizure which lasted about ten minutes. Neurologic examination at this time showed spasticity of the upper extremities and flaccidity of the lower extremities. She started making involuntary movements at 9:00 o'clock in the evening and voided in bed at 11:30. At 12:30 A.M. she responded slightly, fixing her eyes upon the person speaking to her. Blood pressure at this time was 150/70. Throughout the night she gradually recovered some of her responses, awakening at times and responding to stimuli. In the morning she was able to speak a little and her restlessness had decreased. She felt no pain in the operative area and was still getting oxygen *via* the B.L.B. mask. At 9:00 A.M. the oxygen was discontinued since she was feeling much better and responded well to questioning. The blood pressure was now 148/74. During the day it gradually fell to its normal level of 120/70. Subsequently she had an uneventful recovery, and was discharged from the hospital in good condition.

COMMENT: This is an example of cardiovascular collapse following a prolonged major operative procedure where the patient had been carried along on the borderline for several hours. At the close of the operation the patient could no longer tolerate the lowered blood pressure, which itself was being maintained by the body reflexes brought into play to maintain circulating blood volume, and peripheral collapse followed. This might have been prevented by the administration of vasopressor drugs when the last drop in blood pressure to 64/46 was noted. Ephedrine sulphate in place of coramine would probably have produced better results.

The important feature is that once the collapse did occur, vigorous measures were undertaken at once to stimulate the cardiorespiratory system. An improvement was obtained in several minutes, so that the pulse, respirations and blood pressure were within normal limits. The interval, however, had been long enough to produce a moderate amount of reversible brain damage.

The etiology of the interference with respiration in this instance is central. The severe drop in blood pressure caused an ischemia of the respiratory center, producing an apnea of central origin. The mechanical respiratory apparatus was still intact and capable of functioning, but the regulatory mechanism had been removed. When a sufficient supply of blood and oxygen were again made available for the cells of the respiratory center, it resumed its duties, and normal respirations were restored.



The period of anoxia was at the time limit for reversibility of brain tissue damage. It was enough to produce coma and convulsions, but still the patient recovered without sequelae.

**Case 3.**—J. A., a well-developed, well-nourished, 17-year-old white male, with intestinal obstruction of three days' duration, due to postoperative adhesions, was to have a celiotomy performed. Premedication was morphine sulphate gr. 1/6 and atropine sulphate gr. 1/150 subcutaneously 45 minutes before operation.

Ten minutes before the anesthetic was administered, the patient was given 3 mg. of neosynephrin hypodermically. Spinal anesthesia with 150 mg. of monacaine was given in the third lumbar interspace, with the patient in the left lateral position. He was immediately turned on his back and placed in slight Trendelenburg. The blood pressure was 120/74, and the pulse rate 88. After an infusion of physiologic saline solution was begun in the left arm, the patient was draped, and the operation started. His condition did not change until the abdomen was opened and traction was exerted upon the bowel in an attempt to expose the site of the obstruction. At this time the patient gasped that he could not breathe and immediately stopped spontaneous respirations. Pulse and blood pressure were absent, and the skin was ashen gray in color and covered with a cold sweat. The surgeon was advised of the change in the patient's condition and asked to release the bowel. Artificial respiration with the rebreathing bag of the anesthesia machine was started, and caffeine sodium benzoate gr. 7.5 and ephedrine sulphate gr. 3/8 were given intravenously into the tubing of the infusion.

In about five minutes the patient again started spontaneous respirations, and the pulse became of good quality although fairly rapid (140). The blood pressure was now 100/66, but the patient was still unconscious and did not respond to stimuli. The operation was continued and carried to a successful conclusion, with no further change in the patient's condition. It was not until the skin was being closed 25 minutes later that he opened his eyes and weakly asked if the operation was nearly over.

An uneventful postoperative course followed, and he was discharged in good condition.

**COMMENT:** This is an example of shock from a combination of factors—sudden release of intra-abdominal pressure and traction upon a mesentery. These led to sudden peripheral vasomotor collapse, the patient exhibiting typical signs of shock. The prompt treatment restored the cardiorespiratory system, and the period of unconsciousness was only one-half hour, resembling syncope in appearance. The apnea was again the result of sudden severe ischemia of the respiratory center.

**Case 4.**—J. S., a 50-year-old white mechanic, was admitted to the hospital with a chief complaint of diffuse abdominal pain, more severe on the right side, of ten days' duration, and moderate dyspnea. Examination showed pleural effusion on the right side, later confirmed roentgenologically, and marked tenderness in the right flank. A work-up for intra-abdominal pathology, including barium enema, was negative. The day after admission it was noted that the patient had not voided, and nothing was obtained on catheterization. The next day, when cystoscopy was performed under spinal anesthesia, a flow of urine started. Pyelograms showed poor kidney function and bilateral hydronephrosis, and ureteral catheters were inserted to the kidney pelves for drainage. They drained intermittently for six days, when the patient had a severe chill and drainage stopped completely. A right kidney exploration and possible nephrostomy were decided upon.

Spinal anesthesia was selected, since at the first cystoscopy a flow of urine was obtained immediately following the onset of anesthesia, and it was thought that it might again prove of value. Premedication of morphine sulphate gr. 1/6 and atropine sulphate

## COMA WITH SPINAL ANESTHESIA

gr. 1/150 was given subcutaneously at 4:55 P.M. and at 5:40 P.M. neosynephrin, 5 mg. was injected hypodermically. The blood pressure was now 150/86, and the pulse rate 92. At 5:45 the patient was put in the left lateral position, and monacaine formate 150 mg. in 3 cc. of spinal fluid was administered in the second lumbar interspace. The patient was turned on his back for ten minutes and then, at 5:55, was put in the right kidney position, the table broken to an acute angle, and the kidney-bar raised. The operation was started at 6:05, at which time the blood pressure was 132/80, and pulse rate 96, and the patient was apparently in good condition. At 6:20 he complained of difficulty in breathing and was given 100% oxygen *via* the anesthesia machine. At this time his blood pressure was 100/70, and pulse rate 108, and an infusion was started. At 6:25 respirations ceased, the pulse was very weak, and the blood pressure not obtainable. Artificial respiration with oxygen was given by manual compression of the rebreathing bag of the anesthesia machine. The patient was now cyanotic, and there was difficulty in maintaining a patent air-way due to his position on the operating table. The surgeons were asked to hurry, and drains were inserted into the perinephric abscess which had been found, the table straightened, and the wound quickly closed after a biopsy of the kidney. Ephedrine sulphate gr.  $\frac{3}{8}$  was given intravenously at 6:28. At 6:35 the patient was put on a stretcher on his back, and although no pulse or blood pressure was obtainable, his color was now fair, and heart beats could be heard with a stethoscope. Artificial respiration was continued, and metrazol gr. 4.5 was given intravenously. At 6:45 spontaneous respirations were resumed, and an intratracheal tube was inserted. The pulse was now obtainable, weak but regular. At 6:50 the pulse was fairly strong, the blood pressure 90/60, and the patient was returned to the ward.

On arrival at the ward at 7 o'clock, the patient appeared to be comatose, skin cold and clammy, blood pressure 108/64, and pulse rate 92. At 8 o'clock his general appearance was better, the skin was warm, the pulse 88, and the blood pressure 110/80. After the intratracheal catheter was suctioned and some mucus obtained, the patient's breathing was easy and not labored. At this time he coughed, and the intratracheal tube was removed. He still did not respond, and no corneal reflexes were present. At 9:30 generalized twitching movements were noticed, with the patient thrashing about moaning and his eyes rolling. At 10 o'clock he still did not respond, but slight corneal reflexes were noted. At 12 o'clock good corneal reflexes were present, and the patient had convulsive movements of his arms and legs for about five minutes. The next morning, at 4 A.M., the patient still did not respond to questioning but reacted slightly to stimuli. At 10 A.M. the patient was very drowsy but answered sluggishly when questioned. At 2 P.M. he was fully aware of his surroundings and seemed to have recovered completely. The second postoperative day his condition was good except for the persistent anuria. He then gradually sank into uremic coma, and died on the fifth postoperative day.

Postmortem examination showed right lower lobe pneumonia, multiple focal infarctions and abscesses of both kidneys, and adenocarcinoma of the stomach with metastases to the abdominal lymph nodes. Contributing factors were hypertrophy of the heart with chronic pericarditis and right hydrothorax, bilateral adhesive pleuritis and atelectasis. Permission for examination of the brain was unfortunately not obtained.

COMMENT: The anoxia and collapse were due to a combination of factors. The respiratory system was already impaired by the pneumonia and pleural effusion. Superimposed upon this was the position of the patient on the operating table, the exaggerated lateral flexion further impairing respiratory excursions, and the level of the spinal anesthesia paralyzing the lower intercostal muscles. The resultant decreased oxygenation rapidly led to collapse through anoxia of the vital centers.

The patient was revived through rapid cooperation between surgeon and

anesthetist in remedying the etiologic factors as soon as possible while instituting the proper resuscitative measures. Artificial respiration with 100 per cent oxygen was immediately started after the patency of the airway was assured. The cardiorespiratory system was stimulated by the injection of ephedrine and metrazol, with good response.

The patient was comatose for approximately 20 hours, and during this time had several convulsive seizures typical of cerebral damage. He recovered fully from the anoxia, however, since 48 hours postoperatively no changes indicative of central nervous system damage could be demonstrated. He subsequently sank into uremic coma and died.

**DISCUSSION:** Coma during spinal anesthesia is due to a breakdown in the body mechanism supplying oxygen to the brain. In most of the cases presented it assumed the form of acute collapse of the patient and was associated with a sudden fall in blood pressure. The need for an intelligent, experienced anesthetist in charge of the patient's vital functions immediately becomes apparent. If the collapse is recognized as such when it occurs, and the proper treatment instituted with no delay there need rarely be lost a patient under spinal anesthesia. It is when incompetent persons are told to "watch the spinal" and strict attention is not paid to the patient's condition at all times that the collapse is allowed to exist for a period of time that renders irreversible damage. When treatment is instituted too late the patient may linger for some hours or days in coma before expiring. If the critical state of the patient is not recognized at all, the discovery is suddenly made that the patient is dead.

In the treatment of this complication, prophylaxis is the first step to be taken and involves the use of vasopressor drugs as ephedrine sulphate or neosynephrin administered before the spinal. These tend to maintain the blood pressure after the vasodilatory effects of the spinal have occurred. If, in spite of this, the blood pressure falls too low, additional measures must be taken. Small doses of the pressor drugs intravenously will raise the pressure temporarily while intravenous fluid therapy is being started. In any prolonged major operation an infusion should be started before the incision is made. This serves two purposes, providing a means of administering blood or plasma as desired and also keeping a vein open for intravenous medication in an emergency. The fluids thus given also help maintain the circulating blood volume and the patient's blood pressure.

The maintenance of an adequate oxygen intake is a second factor of prime importance. With impaired respiratory effort, the inhalation of high oxygen concentrations (50 per cent to 100 per cent) is sufficient to provide adequate oxygenation. When apnea occurs, however, it is essential that a means of administering artificial respiration be at hand, and there is no better method than one of the closed system anesthetic machines equipped with a rebreathing bag. Intermittent manual compression of the bag will insure alternate expansion and deflation of the lungs providing the air-way is patent. The necessity

for always having a gas machine present during spinal anesthesia is thus demonstrated. Pharyngeal air-ways and an intratracheal set with laryngoscope and catheters should also be at hand if needed.

The position of the patient is of importance. Even though at least a 5° Trendelenburg position should be used during spinal anesthesia, when collapse occurs it should be changed to a 20° angle. This uses the force of gravity to aid circulation to the head and vital centers. Great caution should be exercised in avoiding the mechanical factors which may hamper respiration.

This small series of cases is illustrative of the type in which death would have ensued in several minutes if the anoxia had been allowed to persist. Most deaths under spinal anesthesia are of this type, the patient going into collapse, losing consciousness and dying. If when collapse occurs and consciousness is lost, prompt therapy is instituted, the coma can be reversed, and the patient recover, with no sequelae. In some cases the recovery occurs in a short time, 15 to 45 minutes, and in other more severe episodes of anoxia it may be delayed for up to 24 or 36 hours.

#### SUMMARY

The occurrence of coma during spinal anesthesia is a sign of severe anoxia of the cerebral centers. If this anoxia is allowed to persist for more than several minutes, death ensues, but when it is recognized as such as soon as it occurs and the proper physiologic therapy instituted immediately, the condition can be remedied and the patient saved. In some instances the recovery is preceded by a period of coma lasting up to 24 hours.

The therapy consists of prompt administration of oxygen, vasopressor drugs when necessary, Trendelenburg position, patency of the air-way and intravenous fluids. In order to be able to carry out this regimen the following precautions should be observed:

- (1) A competent anesthetist should always be present and in charge of the patient's vital functions.
- (2) An anesthesia machine should be in the room.
- (3) A tray of stimulant drugs and syringe at hand.
- (4) Pharyngeal airways and endotracheal equipment at hand.
- (5) Use of Trendelenburg position.
- (6) An infusion in major cases to provide a patent vein in case of peripheral collapse.

If these precautions are observed and immediate corrective measures taken when trouble does occur, the diagnosis of death from collapse of the patient under spinal anesthesia will rarely be made.

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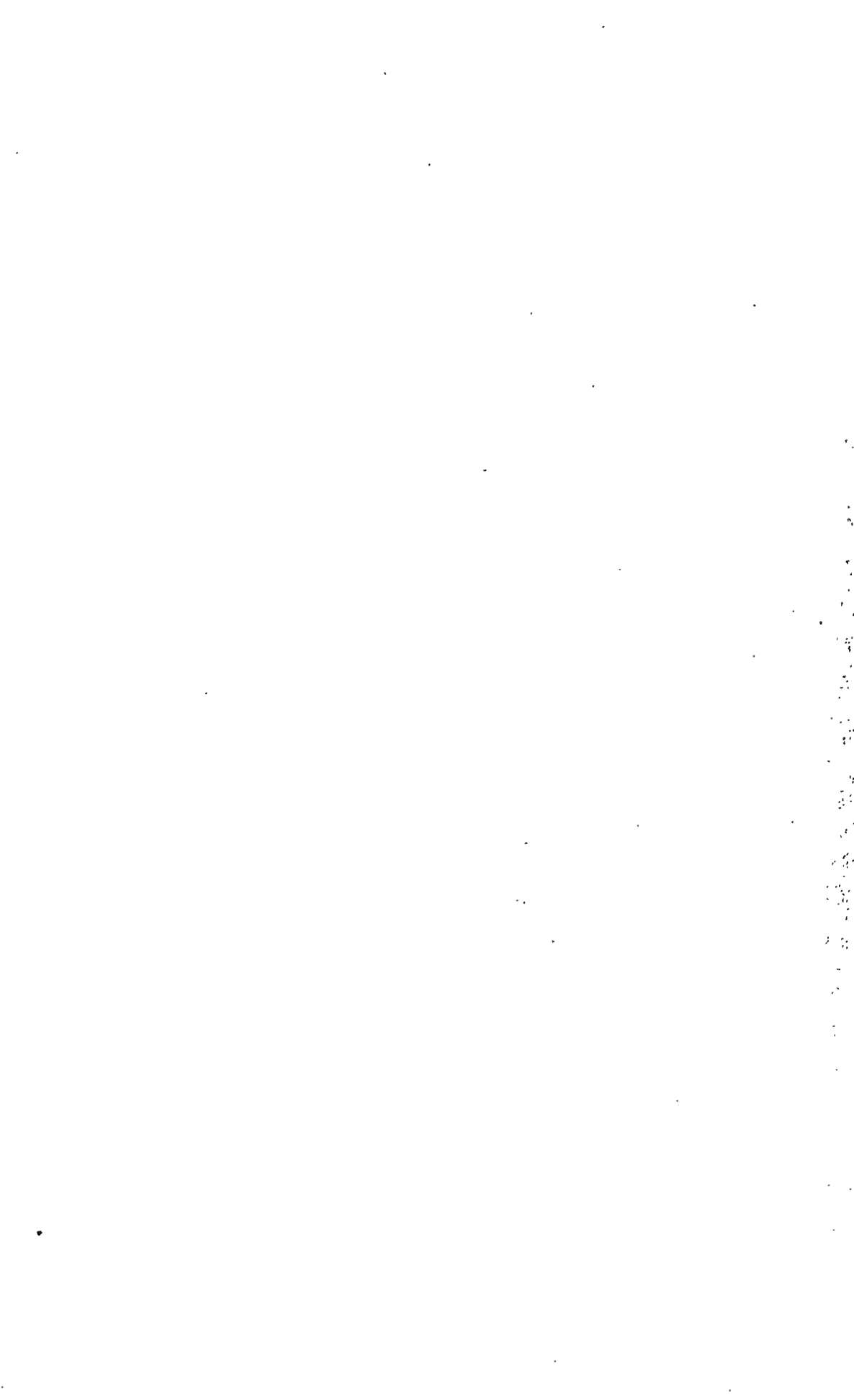
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REPARATIVE SURGERY OF COMPOUND BATTLE FRACTURES  
IN THE MEDITERRANEAN THEATER OF OPERATIONS

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EXTREMITY SURGERY of the war wounded is divided into three phases<sup>1</sup>:

1. *Initial*: The primary excisional surgery performed in Army Field and Evacuation Hospitals as soon after wounding as possible (usually 8-24 hours) directed at the saving of life and limb and the prevention of infection.

2. *Reparative*: Performed in fixed hospitals at the Base directed at wound healing, anatomic and functional restoration of the extremity and rehabilitation or safe transport to the Zone of Interior in a lag-period of treatment after all that is necessary in the overseas Theater to minimize permanent disability has been achieved.

3. *Reconstructive*: Performed in the hospitals of the Zone of Interior directed at correction of residual defects and deformities resulting from the war wound.

Reparative surgery is largely dependent upon adequate initial surgery,<sup>2</sup> including bold incision, excision of dead and devitalized tissue, good drainage of the wound depths and dead space, an occlusive dressing, and adequate immobilization. It is facilitated by a short line of evacuation which permits transferring of the patient within a few days after wounding to a Base Hospital that is functioning close behind the combat zone. When these conditions are ideally fulfilled, surgical repair of open wounds is a logical and successful procedure in wound management. If the initial surgery has been inadequate, additional excisional surgery anticipating staged repair is usually necessary to prevent or cut short wound sepsis. Successful reparative surgery may make reconstructive surgery unnecessary or may return the patient to the Zone of Interior in a condition that will permit earlier and complete reconstructive surgery with enhanced chances of success.

## CONCEPT OF REPARATIVE SURGERY

Since the early days of this Theater in North Africa, repeated observation has established that wounds with obviously retained devitalized tissue became septic and drained pus profusely. Large hematomata in undrained dead space often decomposed into pus. Systemic or local chemotherapy, or their combination, did not prevent wound sepsis in the presence of dead tissue. Once wound sepsis had developed, there was continuing local



necrosis of living tissue and a vicious circle was established. Large granulating areas exuding plasma were observed to develop and harbor surface infection. These septic wounds, however, seldom manifested the cardinal signs of inflammation. Conversely, wounds which were free of devitalized tissue on their admission to Base Hospitals were clean grossly and free of sepsis. As healing by granulation occurred, many developed surface infection.

Following these observations, reparative surgery began with the successful secondary closure of clinically clean soft-part wounds, even though cultures taken preoperatively demonstrated the presence of an aerobic and anerobic bacterial flora.<sup>1, 2, 4, 5</sup> A wound free of devitalized tissue sutured at its primary dressing, four or five days after initial surgery, without dead space, hematoma in the depths, or excessive tension, and supported by a good pressure dressing and adequate splinting healed regardless of the bacterial flora. Successful suture depended upon a proper clinical appraisal of the wound, atraumatic technic, and surgical limitations imposed by the character of the defect. The clinical observations supported by the bacteriologic studies of Lyons and Rustigian<sup>3</sup> on war wounds which demonstrated that clean wounds and wounds with established sepsis may have comparable bacterial flora, have led to the following concept:

Wound sepsis becomes established as a result of the septic decomposition of devitalized tissue, including hematoma in dead space, rather than from the action of bacteria on living tissue. The devitalized tissue serves as a pabulum<sup>3</sup> for wound pathogens. If the pabulum is not present and is not created by surgery, and if living tissue is protected from invasive infection by an effective antibacterial agent, the bacterial flora of an open wound may be disregarded, wound sepsis need not be feared, and any indicated reparative procedure may be performed under established surgical principles with the anticipation of good wound healing.

Battle-incurred compound fractures demand special considerations when compared with those resulting from traffic and other accidents. Battle fractures are always compounded from "without-in" by missiles which have passed through clothing, often soaked with the grime and mud of the battlefield. The great majority are caused by high explosive shell fragments resulting in extensive muscle and bone damage. Clothing, wood, metallic foreign bodies, cement and mud are frequently buried in the depths of the wound far removed from their point of entry. In spite of excellent field service in this Theater for evacuation of the wounded from the battlefield to a hospital equipped for surgery, the time-interval between wounding and initial surgery usually exceeds 12 and often 24 hours. Accordingly, the wounds are not merely contaminated but are heavily infected with bacteria. The fractures are usually severely comminuted, often with bone loss. These injuries require long incisions, often multiple, for adequate exposure of the devitalized tissue and foreign material and to permit adequate excisional surgery. The large, often irregular, or multiple wounds made by surgeon

and missile must remain unsutured following initial surgery. They, together with muscle and bone loss incident to the injury and the surgery, present a picture and a problem peculiar to military surgery.

Reparative surgery recognizes that complete excision of the devitalized tissue in compound battle fractures is usually impossible or impracticable. At initial surgery, completely detached bone fragments are deemed to be avascular tissue and potential sequestra and, therefore, they are removed together with the devitalized soft tissue. Fragments with complete or partial periosteal attachment are preserved projected towards union of the fracture. Muscle, fascia, tendon, and periosteum attached to the fragments and the denuded cortex of bone constitute questionable devitalized tissue which probably remains in every fracture. Blood clot may form in an undrained area particularly in the dead space of the unreduced fracture or the defect created by the necessary muscle excision. The wounds of these injuries which have had adequate initial surgery have been observed in many instances to be draining profusely on admission to the Base Hospital. Unless wound sepsis became established, the profuse drainage ceased after several days. The discharge has been attributed to the spontaneous sequestration of the residuum of devitalized tissue and has been termed "the products of injury necrosis."<sup>16</sup> However, it is recognized that the residual devitalized soft tissue, partially denuded fragments, or dead space with a contaminated blood clot may be a nidus of infection with wound pathogens,<sup>3</sup> leading to abscess formation with continuing necrosis of living tissue within the wound. These are some of the factors that create specialized problems in the reparative management of compound fractures.

Every method of treating compound fractures seeks to obtain bony union with minimum deformity, a healed wound and maximum function of the extremity. During the year 1943 and early 1944, in the North African Theater of Operations, compound battle fractures were treated by a modified Orr method,<sup>6</sup> consisting of an open wound, infrequent occlusive dressings and traction or plaster immobilization. Wound healing by granulation and the resultant scar formation were accepted as necessary undesirables. In certain instances poor fracture results, malunions, or inevitable nonunions were accepted rather than risk "a stirring-up" of the wound by an open reduction. Wound sepsis with continuing local necrosis of living tissues became established in many cases, particularly in the exposed fracture sites of subcutaneous bones. Wounds with gross retained dead tissue were often managed by a "hands-off" policy which anticipated the spontaneous sequestration of the dead tissue rather than a delayed surgical excision. The unreduced fracture which called for repeated manipulations or adjustments of position in traction was particularly vulnerable to sepsis. A proper appraisal of the problem demonstrated the need for improvement which could be achieved only by a changing approach.

With a background of a year's experience, study and observation in the Theater of Operations, reparative surgery of compound fractures was

visualized and partially planned during the late months of 1943. Following in the wake of successful reparative management of soft-part wounds, it was initiated during the first quarter of 1944, catalyzed by the availability of penicillin therapy.\* During the memorable days of Cassino and Anzio, it developed into a plan of management based upon continuing pooled experiences of the Theater surgeons.

In this Theater certain previously planned favorable operations factors obtained:

1. Experienced Forward Hospitals with standardized principles of excisional surgery and transportation splinting.
2. Short chain of evacuation, ambulance and train (Cassino), and air evacuation (Anzio) from Forward to Base Hospital predisposing to safe early transfer of the wounded.
3. Experienced Base Hospitals functioning close behind the combat zone.
4. A bed status in the Base that permitted the patients to be held for reparative surgery and rehabilitation or transfer to the Zone of Interior.
5. An Army blood bank supplying low titer-O blood to and augmenting that drawn in Forward Hospitals and unit banks in each Base Hospital supplying type specific blood.

Such was the prologue for reparative surgery of compound fractures at the "Fall of Rome."

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The reparative surgical program for compound fractures has as its objectives: 1. Minimum wound sepsis. 2. Improved fracture reduction and stabilization. 3. More rapid wound healing, with minimum scar formation. 4. Maximum functional restoration of the extremity.

These objectives are approached by a plan of management based upon: (a) Blood replacement. (b) Chemotherapy. (c) Surgery. Good surgery is the keystone of the program, with blood replacement and chemotherapy as adjuncts.

#### BLOOD REPLACEMENT

In spite of what is considered to be an adequate use of blood replacement therapy in the forward area to combat shock, traumatic and operative, patients with compound fractures of the long bones have consistently shown anemia on admission to the Base. Tables I and II show the hematocrit readings obtained in two groups of battle casualties on admission to Orthopedic Sections of two General Hospitals. The tables are separated to allow column 4 of Table I to be presented as evidence of the blood loss sustained by a patient with a battle-incurred fracture of the femur. It will be noted that 50 per cent of this group had hematocrits under 30.

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\* The counsel and active participation of Major Champ Lyons, M.C., of the staff of Surgical Consultant, M.A.T.O.U.S.A., was invaluable in the development of the program.

## COMPOUND BATTLE FRACTURES

TABLE I(7)

Hematocrit	No. Cases	Percentage	No. Cases of F.C.C. Femur
Under 30.....	33	24%	19
31-35.....	24	17%	9
36-40.....	56	40%	8
Over 40.....	25	18%	2
	<hr/> 138	<hr/> 100%	<hr/> 38

TABLE II(8)

Hematocrit	No. Cases	Percentage
Under 30.....	37	22%
30-36.....	44	26%
37-42.....	54	32%
Over 42.....	31	19%
	<hr/> 166	<hr/> 100%

In order to correct the secondary anemia, type-specific cross-matched whole blood is given preoperatively in an effort to obtain an hematocrit reading of 40, or better, in all compound fractures on which any major reparative procedure is contemplated. Preoperative blood requirements are calculated on the basis of 500 cc. for each three to four points deficit of the hematocrit. There is no proof that this therapy is necessary but it is accepted *a priori* that the wounded man with an hematocrit of 40 is in better condition to withstand a long anesthesia and operative procedure than if his anemia is uncorrected. Additional blood to compensate for operative loss is frequently given during the operation and postoperatively if anemia is reestablished. Repeated observations by many surgeons that the patients tolerated well and "looked good" after the surgery is sufficient to justify this use of blood replacement therapy. It has not been possible to compile confirmatory evidence, but blood therapy is believed to aid in the prevention of chronic sepsis, and in wound healing.

### CHEMOTHERAPY

Penicillin has been accepted as the most powerful available antibacterial agent to which the bacterial flora, aerobe and anerobe, of war wounds have been proven sensitive. It is recognized that penicillin will protect *living* tissue against invasive infection but it is also recognized that penicillin will not sterilize dead, devitalized or avascular tissue which, inadvisably or of necessity, remains in the wound, nor will it prevent the septic decomposition of a contaminated blood clot which collects in unobliterated or undrained dead space or neutralize locally necrotizing enzymes in undrained pus.<sup>9, 10</sup> Therefore, penicillin is used for the protection of the living tissue from the invasive action of bacteria accepted as present in the residuum of devitalized tissue remaining in compound fractures. The agent will not sterilize that residuum, therefore, surgical measures are necessary for its management. Therapy is continued until wound surgery has been completed, wound healing has been sufficiently obtained and the residuum of devitalized tissue has sequestered and drained off or has absorbed. Penicillin therapy is used to provide an increased margin of safety in the performance of the indicated surgery.

Penicillin is used routinely and no advantage can be seen in attempting the surgery without it. While there is no proof that it is a necessity, and

although successful reparative procedures on compound fractures without it have been reported, there are two cases on record in which gas gangrene and death followed reparative operations upon compound fractures without the use of the agent. No deaths or serious untoward results from sepsis have been reported in similar cases receiving penicillin therapy as an adjunct to the surgery.

Systemic administration of penicillin, 25,000 units intramuscularly every three hours is the basic therapy. Local instillation into joints, 1,000 units per cc. is supplemental. Otherwise no local therapy is used in extremity surgery.

Patients with compound fractures as a rule are receiving penicillin therapy in the Evacuation or Field Hospital when they are transferred to the Base. Therapy is reinstituted on admission to the Base Hospital and continued until five to ten days after the last traumatizing surgery (which may produce more devitalized tissue) until as outlined above, the wound has sufficiently healed and contaminated devitalized tissue is no longer in evidence.

#### SURGERY

The surgery is aggressive rather than passive. Wounds are explored to insure the adequacy of the initial surgery, fractures may be fixed internally and soft-part wounds may be sutured. But the success of the program depends upon the quality of surgical judgment and technic. Every case requires a decision as to the anesthetic; the extent of further excisional surgery; whether to use some form of internal fixation; the extent of closure of the compounding wound possibly aided by relaxing incisions or flaps; whether, where and how to drain; and the postoperative method of obtaining or maintaining reduction.

Five to ten days will have elapsed since initial surgery before the patient with a compound fracture is ready for reparative surgery. With adequate blood replacement, continuing penicillin therapy and good roentgenograms made in the Base Hospital, he is anesthetized in an operating room prepared for any indicated surgery, be it *excisional* or *reparative*. There, the Evacuation Hospital encasement and dressing are removed, the extremity prepared and draped and the wound inspected. A pneumatic tourniquet is frequently used not only to provide a "dry" operative field but to minimize blood loss on the table.

*Wound Revision:* The entire wound including the fracture site is exposed by gentle retraction and explored to insure the adequacy of the initial surgery. Incisions are enlarged if necessary to facilitate exposure. Any remaining foreign material, accessible foreign bodies, totally detached bone fragments or devitalized soft tissue are removed. Old blood clot is cleaned out. Means by which dead space may be obliterated or drained are considered. Further excisional surgery is not infrequently indicated. Failure to perform wound

revision soon after admission to the base is believed to account for many poor results seen in the past. Muscle tissue which appeared viable at initial surgery and, therefore, was not removed may have necrosed in the interim. When the remaining devitalized tissue of dirty wounds was not excised, wound sepsis with continuing local necrosis of living tissues was often established. Late wound exploration in cases of established sepsis has frequently revealed foreign material, or totally detached indriven fragments of cortical bone. Their removal plus proper reparative surgery was followed by subsidence of wound sepsis (Cases 1, 2 and 15). Reduction to the minimum of residual devitalized tissue is the most important step towards the minimizing of sepsis and is the keystone of the plan of management. When sepsis intervenes, reparative measures are doomed to failure, delayed or nonunion may follow, and wound healing will be postponed or prevented.

*Fracture Management:* The thorough wound visualization of reparative surgery affords the advantages of open reduction of fractures. Intervening soft parts are removed. Fragment ends caught in muscle are released. Rotated and twisted fragments are aligned. Complete appraisal of the problem at hand by direct vision as well as by roentgenogram is valuable in determining the means of obtaining and maintaining fracture reduction. The best possible fracture reduction is the objective of fracture management. In addition to the anticipated favorable anatomic result, stabilized fracture reduction eliminates the dead space of an unreduced fracture, and avoids traumatizing multiple manipulations or adjustments of traction in delayed efforts to effect reduction, thereby minimizing the chances of sepsis. In an effort to achieve the maximum fracture reduction, internal fixation is sometimes used under the following principles:

*Internal Fixation:* Internal fixation is by no means an objective of the program, and it is usually neither advisable nor possible because of severe comminution. However, the program permits the use of internal fixation with the limitations outlined below when it is *indicated* to maintain fracture reduction. Eighteen and eight molybdenum steel is relatively inert in the tissues and is not considered *per se* detrimental to wound healing. The fixation may be plating, multiple screws or wire loops.

The rigid stabilization of the fracture in reduction by a plate or multiple screws offers certain advantages (Cases 3, 4, 8, 11, 12):

1. Anatomic opposition and alignment anticipating faster bony union with no deformity.
2. The dead space and traumatizing manipulations outlined above are avoided.
3. Handling of the extremity for necessary subsequent wound care is facilitated.
4. Early joint motion and muscle exercise anticipating a more rapid return to function may be permitted.
5. The management of concurrent injuries which preclude traction and require repeated trips to the operating room is facilitated.

However, the use of internal fixation is limited by three factors other than comminution:

1. The desire to minimize intrawound trauma, *e.g.*, retractor pull, vessel ligatures—which creates additional devitalized tissue.

2. Interference with the covering of all exposed bone cortex with vascular soft parts (to be discussed under closure) (Case 5).

3. The desire to avoid periosteal stripping with its danger of massive sequestration which may be necessary to permit the application of a bone plate (Case 6).

When periosteum is stripped from bone, the outer cortex will die.<sup>11</sup> A basis for this statement is the experimental observation in dogs that the periosteal blood supply nourishes the outer third of the cortex of shafts of long bones.<sup>12</sup> If there is no sepsis, the dying bone is replaced by new bone as one process. But if sepsis is present reattachment of periosteum or other soft parts is prevented and the outer cortex becomes a sequestrum. Therefore periosteal stripping which deprives the outer cortex of bone of its nourishment is an important consideration in surgery in a known "infected" field. Practically, if the wound is appraised clean and the other factors are favorable, especially the availability of vascular soft parts, as in the arm or thigh, there is less hesitancy in stripping sufficient periosteum to permit the indicated surgery but if it is appraised "dirty"\* or doubtful, the stripping is restricted or avoided.

Where the factors that might restrict its use are not unfavorable and the fracture permits, rigid internal fixation is frequently employed in order to gain the advantages of a well-reduced and stabilized fracture. Fixation through the compounding wound is at times practical but has the disadvantages of retraumatizing tissue and placing the metal on bone usually devoid of periosteum and at the bottom of dead space created by excision of devitalized muscle. Therefore, for plating, a separate standard approach to the fracture which permits covering of the bone and metal by periosteum and vascular soft parts is advisable (Case 4).

Every refinement in the technic of internal fixation is considered important. There must be intimate contact of the fragments; plate should be sufficiently long (Murray<sup>13</sup> recommends that the length of the plate be five times the diameter of the bone at the fracture); drill holes should be only slightly larger than the shaft of the screw, less the threads, preferably at right angles to the bone and wobbling of the drill or a drill bit at an angle should be avoided to prevent scoring of the drill hole. (Electrically driven drills require extreme caution to prevent burning of the bone); screws

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\* The term "dirty wound," as a contrast to clean wound is in common usage in this Theater and is herein used to describe the wound which is visualized to contain gross, unexcised devitalized tissue, is discharging pus, often foul-smelling, from the depths of the wound, or is covered by a gray, slimy purulent exudate. Cardinal signs of inflammation are not necessarily present in the dirty wound. When they are present, the wound is said to present "invasive infection."<sup>16</sup>

should be held "true," inserted by a steady hand and be long enough to protrude through the opposite cortex. Oblique screws across the fracture in a plane at or near 90 degrees from that of the plate will increase the rigidity.

In actual practice when internal fixation is deemed indicated multiple screw (two or more) fixation is frequently used (Cases 7, 8 and 11). Many fractures by their obliquity lend themselves to it, little or no additional periosteal stripping is required to permit placement of the screws, and intrawound trauma is not excessive. If the fracture does not permit rigid fixation because of comminution, one or more wire loops may be used to hold major fragments in approximation. These can usually be placed without additional periosteal stripping, a factor of particular importance in a wound with recognized established sepsis. In comminuted fractures with segmental bone loss, wire loops permit approximation of the major fragments (Cases 9 and 10).

Bony union is a prime consideration in any fracture and contact of the fragments greatly enhances the chances of union. Therefore the shortening of an extremity to overcome segmental loss and obtain contact of fragments is often a justifiable indicated procedure that is permitted by reparative fracture surgery. Nerve trunk or muscle group deficits associated with a fracture may indicate the deliberate removal of attached bone fragments and shortening of the extremity, thereby permitting restoration of continuity of all the severed major structures projected towards the maximum functional restoration of the extremity instead of a good fracture result as determined by the roentgenogram.

*Wound Closure and Drainage:* Wound closure is premised upon adequate initial surgery resulting in a clinically clean wound requiring little or no wound revision or traumatizing surgery and upon the feasibility of obliterating or draining dependently the residual dead space. The lag-period between initial and reparative surgery permits drainage of the products of injury necrosis. If initial surgery has been inadequate, resulting in a clinically dirty wound requiring extensive excisional surgery at wound revision, wound closure must be staged until after an additional lag-period for open drainage.

The hazards of an open wound in a compound fracture are the sequestration and sloughing of exposed bone cortex, tendon and fascia, plus reinfection at dressings and slow wound healing by granulation. The advantage of an open wound is continuing drainage from the depths of the wound until healing by granulation has sealed-off the fracture site. The gaping wound forms a natural channel for drainage. However, when it is not dependent and sepsis intervenes, there may be pocketing, puddling or pooling of pus in the fracture site or adjacent fascial planes with continuing local necrosis of the collagenous tissues.

Reparative surgery of compound fractures recognizes and attempts to overcome by wound closure the hazards of the open wound but also recognizes the advisability of a means of egress for the possible septic breakdown of any residual devitalized tissue not yet separated and of a contaminated hematoma



in unobliterated dead space. In the uninfected field, *e.g.*, the simple fracture or following a clean surgical operation, body processes will absorb devitalized tissue and blood clot. In the infected\* field the same absorption might occur but the complete closure of wounds of compound fractures is justified only when the pabulum for wound sepsis is *nil*. A deep abscess about the fracture site underneath a sutured or healed epithelial bridge may produce irreparable damage. Therefore, an increased margin of safety can be obtained by providing drainage, dependent if possible, utilizing wounds or counterincisions as indicated. Drains are inserted so as not to cause tissue necrosis and are removed between the third and tenth day depending upon the drainage indications before rigid sinus formation occurs.

The problem of closure of the compounding wound is approached with the major objective of covering exposed bone cortex, tendon and fascia with healthy soft parts and the minor objective of reducing skin defects to a size that is compatible with *adequate* drainage. The sliding or rotation of flaps is often employed to gain these objectives (Cases 11 and 13). The hazard of periosteal stripping finds its antithesis in the value of covering bone exposed by trauma. Soft parts must adhere to the bony cortex to permit its "revascularization," whereby the dying bone may be absorbed and replaced by new living bone. Otherwise sequestration is inevitable (Case 15). Therefore, wound closure is designed to obviate the hazards of exposed bone cortex the salvage of which is probably the most important attainment of reparative surgery of compound fractures (Cases 10, 11, 13 and 14).

When soft-part masses fall over and protect structures that are vulnerable to exposure, *e.g.*, the muscles of the thigh over the femur, the major hazard of the open wound is removed and surgical closure is of less importance. The open wound may be the optimum method for free drainage and is utilized when closure, complete or partial, affords no definite advantages. The closure of a small wound compounding a fracture of the femur is inconsequential as the soft parts will be healed before the bone unites.<sup>2</sup> The open wound is particularly advantageous for drainage following traumatizing surgery, *e.g.*, extensive wound revision for dirty wounds or difficult internal fixations (Cases 3 and 4). In such cases, skin suture is avoided or staged. However, skin defects usually may be reduced and still permit adequate drainage. When the wound is clean and requires no traumatizing surgery, and when dead space is at a minimum, skin may be sutured completely or with a small drain of dry fine-mesh gauze or soft rubber tissue emerging through the most dependent portion of the wound or a counterincision (Cases 8, 9 and 10). When two wounds compound the fracture, one may be closed completely and the other (usually the more dependent) left open or partially closed, with or without drainage material. Surgical limitations, *i.e.*, tension, dead space or difficult dependent drainage as in anterior wounds over fractures of the tibia, may preclude wound suture and

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\* Infected, herein, denotes only the recognized presence of a bacterial flora capable of establishing wound sepsis in the presence of dead tissue.

the wound may require loose packing anticipating healing from the bottom by granulation (Orr method) (Cases 7, 8 and 14), but in many of these, partial wound closure may be employed to cover exposed cortex of bone. Partial wound closure in reducing the magnitude of compounding wounds facilitates the sealing-off of the fracture site by healing processes rather than attempting the immediate conversion of the compound to a simple fracture and, therefore, it is frequently employed to reduce the size of defects of the compounding wounds. The reduction to a minimum of skin defects minimizes scar, promotes earlier wound healing and leads to improved functional results.

*Postoperative Management:* Immediate adequate reduction and stabilization of the fracture is essential to reduce dead space, prevent the continuing trauma of fragment ends, and provide wound rest to promote wound healing. In many cases sheet wadding and plaster encasements for immobilization of the fracture in reduction provide pressure dressings for the control of dead space and wound edema. When skeletal traction is the method of choice for postoperative fracture management, the wounds are supported by bulky dressings and elastic bandages. Variations of, and adjuncts to, skeletal traction methods are frequently employed in obtaining and maintaining fracture reduction, *e.g.*, Army leg splint, "Navy" traction, two-wire traction<sup>14</sup> (Plate 1). Anesthesia is often continued until the completion of the traction set-up on the ward permitting immediate manual reduction verified roentgenologically. By this plan, reduction in traction is quickly obtained, and it is maintained by the skeletal traction. Fractures fixed internally are also immobilized externally by plaster or skeletal traction. In the postoperative management of internally stabilized fractures of the femur, skeletal traction affords added protection and permits adequate wound care, early knee motion and physiotherapy.

The case reports and illustrations which follow are presented to illustrate the details of the principles of reparative surgery as applied to compound fractures. Each case demonstrates the application or omission of one or more of the principles covered in the manuscript. While the majority of the cases in the group illustrate results to be anticipated by reparative surgery, cases illustrating certain pitfalls that occurred during the formative stage of the program are included to emphasize certain conclusions.

Internal fixation has been used in nine cases, herein reported, including two cases of wire approximations of major fragments. The predominance of internal fixation in these reports should not be interpreted to mean that the method is employed in the majority of cases, for such is far from true. The group of cases included illustrate the *indications* for the method and concurrently, other principles. Skeletal traction (Plate 1-a-e) is the usual method of obtaining and maintaining fracture reduction when traction is necessary.

Penicillin therapy, unless otherwise stated, and blood replacement therapy were used in each case according to the plan outlined in the manuscript.

PLATE I

A. Fracture of the femoral shaft in the midthird in balanced suspension skeletal traction utilizing the Army leg splint with the Pierson attachment and a Kirschner wire through the tibial tubercle. The leg splint.—Pierson method is used in the majority of cases.

B. Fracture of the upper third of the femur in balanced skeletal traction, utilizing the "Navy" method. It is an excellent method for upper third fractures, with high thigh or posterior wounds.

C. A ward of fractures of the upper third of the femur treated in balanced skeletal traction, employing the "90-90-90" method (the hip, knee and ankle joint position). After a few weeks in this position during which posterior wound management and fracture reduction is effected, the leg splint—Pierson method is substituted.

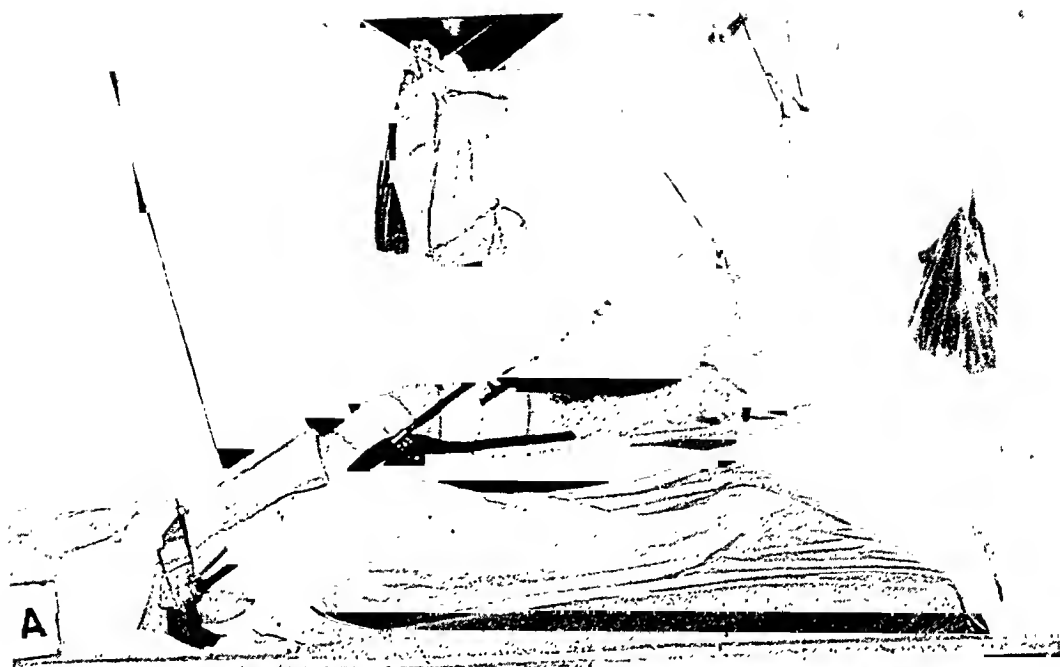


PLATE I (CONTINUED)

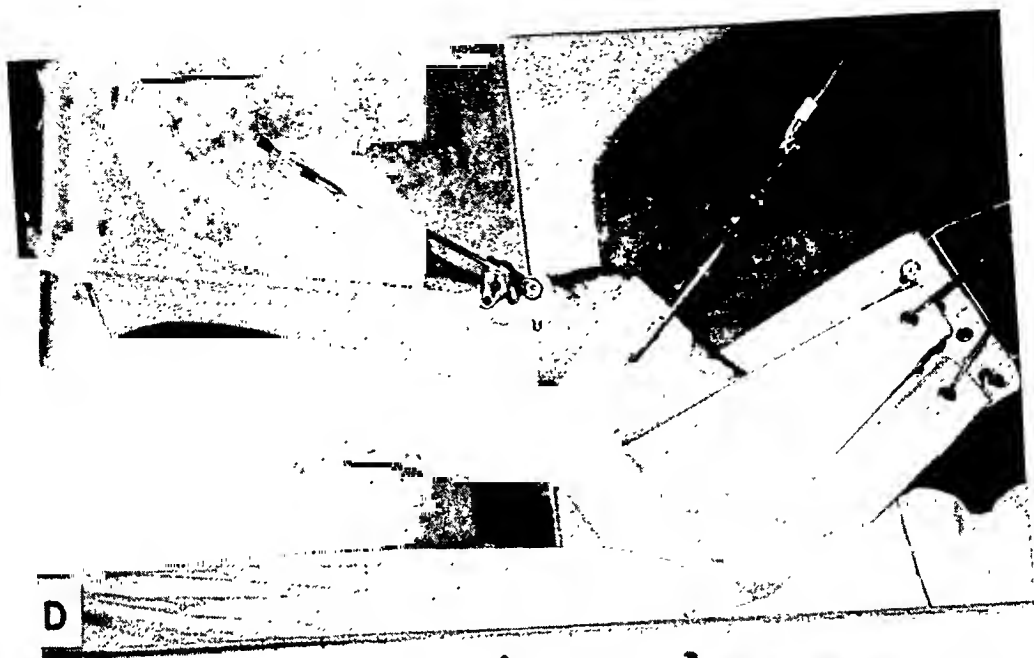


PLATE I (CONTINUED)

D. Two-wire, or double skeletal traction, here used as an adjunct to the "Navy" method for management of a fracture of the lower third of the femur. The two-wire method as illustrated is almost a routine for displaced lower third fractures.

E. "Encasement Traction," a modification of skeletal traction through the os calcis, is a valuable method of maintaining adequate reduction of fractures of both bones of the leg.

F. The "hanging cast"—the most frequently employed method for obtaining and maintaining reduction of fractures of the humerus.

G. A folded towel for support of the arm and traction over a pulley at the foot of the bed permitted by the loop of plaster are employed during temporary recumbency after the reparative surgical procedure.

## PLATE II

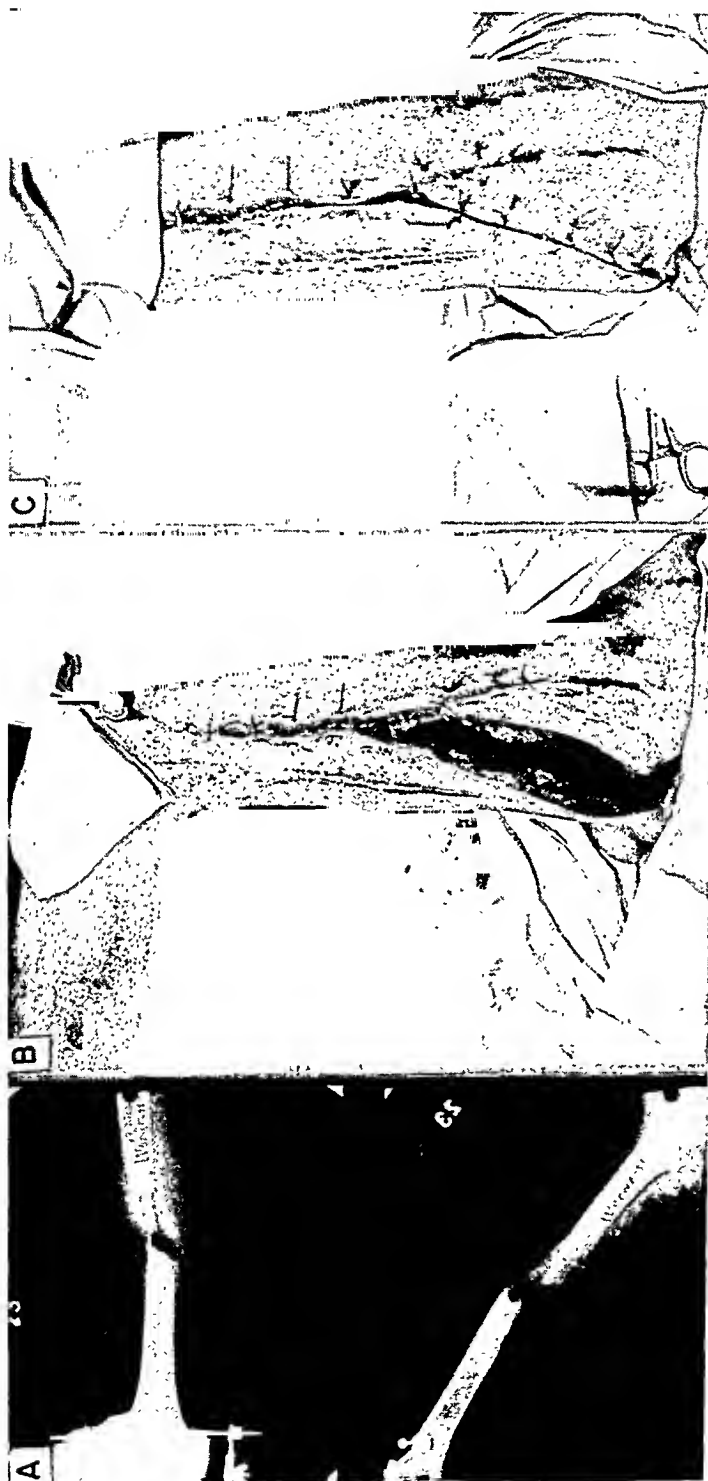
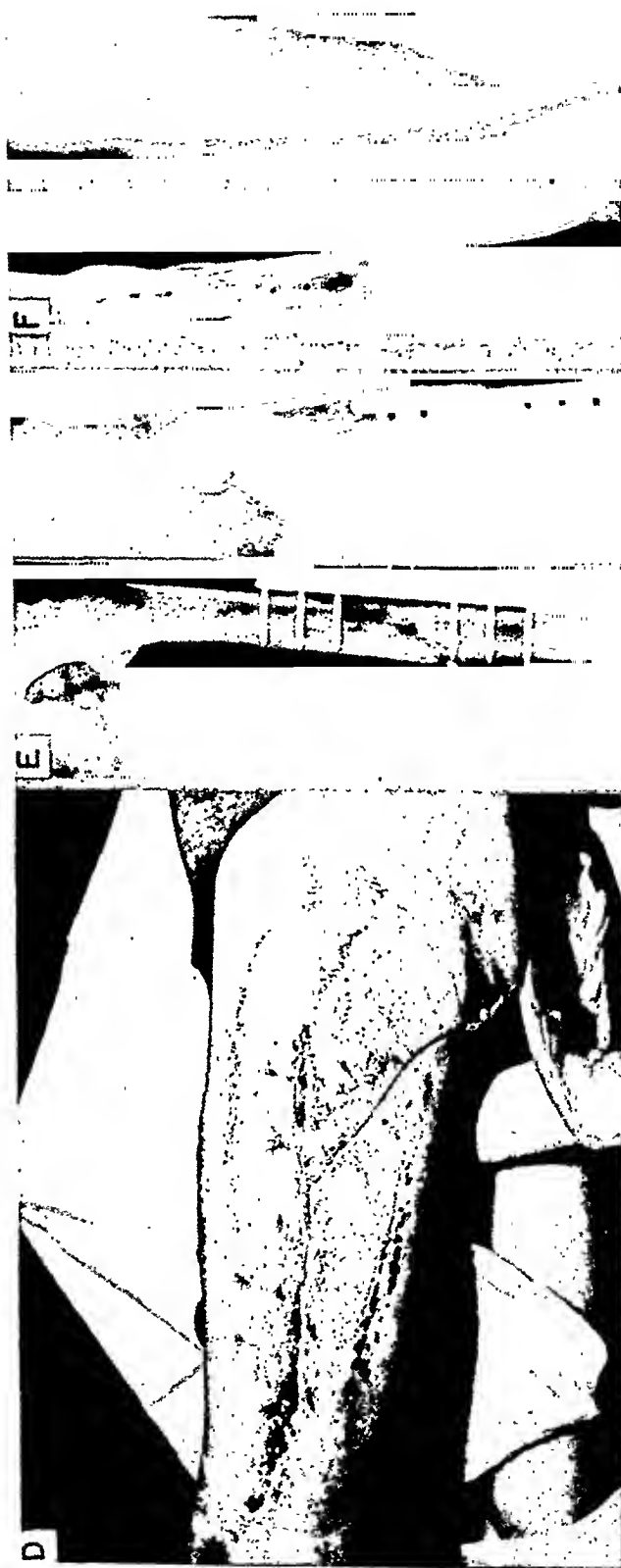


PLATE II.—Case 3: A. Roentgenograms, 13 March, 1944, one month after injury, with the extremity in skeletal traction, revealing distraction and gas abscess formation.

B. Partial wound closure and gaping dependent open wound for drainage at reparative surgery on 15 March, 1944.

C. Staged closure of the remaining portion of posterior wound over a small drain on 21 March, 1944.

PLATE II (CONTINUED)



D. 28 March, 1944. Wound healing has been obtained, except for the small granulating areas in the old compounding wound and at the proximal end of the drainage incision.

E. Roentgenograms showing the internal fixation and suggestion of sequestrum formation. Made in Z of I in July, 1944.

F. Roentgenograms showing end-result.



## PLATE III

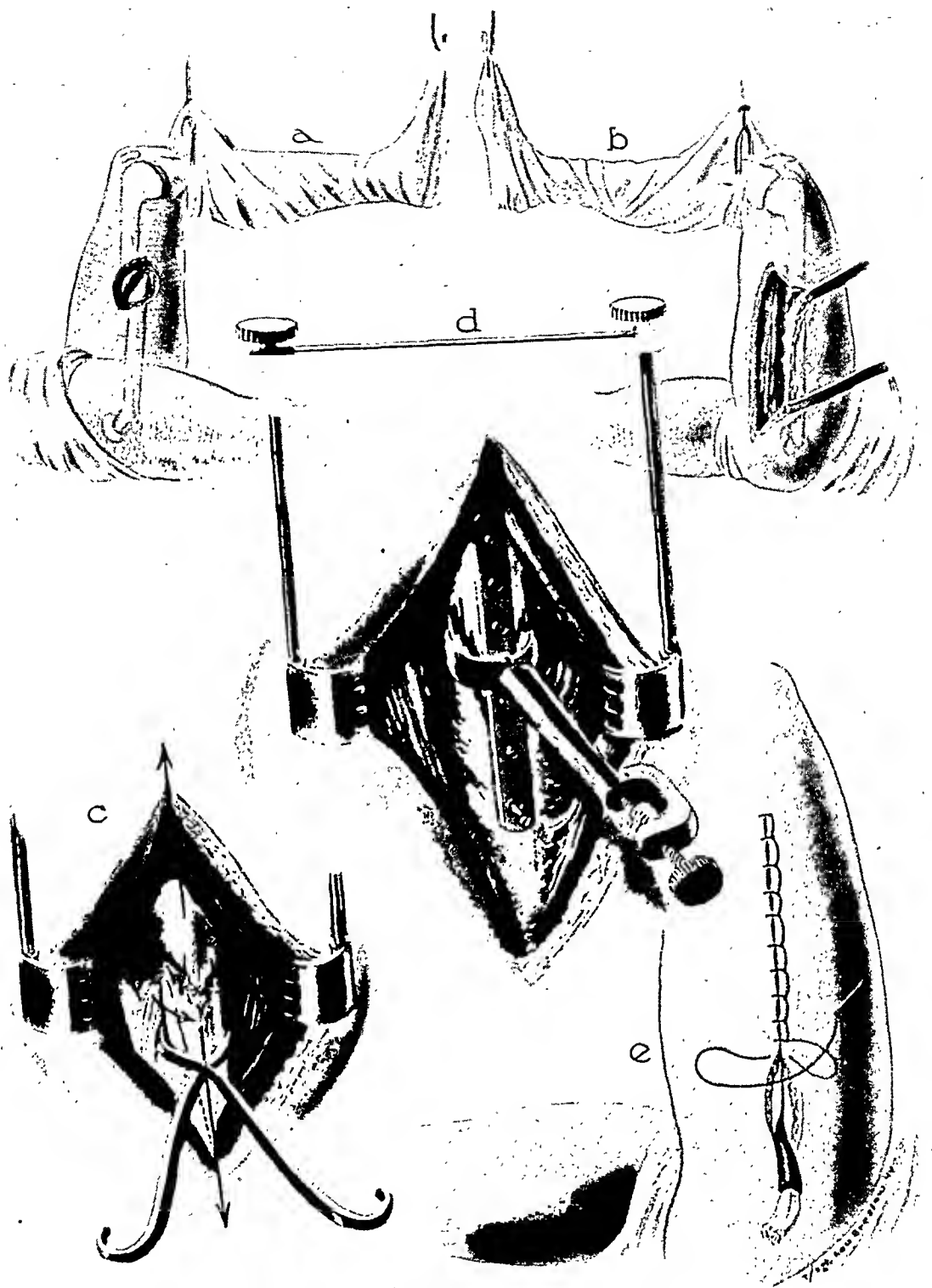


PLATE III.—Case 4: a. Compounding wound.

b. Posterolateral approach.

c. The fracture reduction.

d. Internal fixation.

e. Closure of the operative wound, with drainage. The artist has failed to depict comminution and an obliquity in the fracture.



PLATE IV.—Case 5: A. The wounded extremity prepared for reparative surgery on 3 April, 1944.  
B. The fracture stabilized by the plate passing over a large fragment.

C. The closed operative wound and the converted relaxing incision through which drainage was planned.

D. Roentgenograms made pre- and postoperative. Note the hair line reduction of the fibula in the postoperative films (on left). Conversely, plating of the fibula will produce adequate reduction of a severely comminuted tibia.

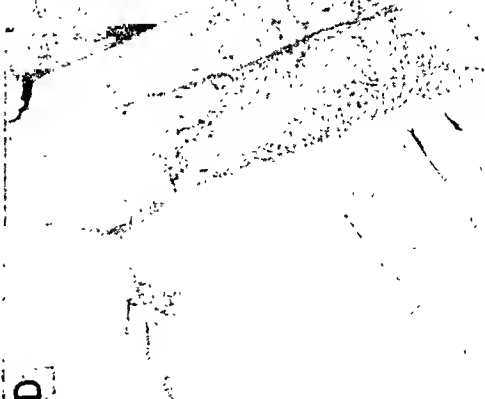
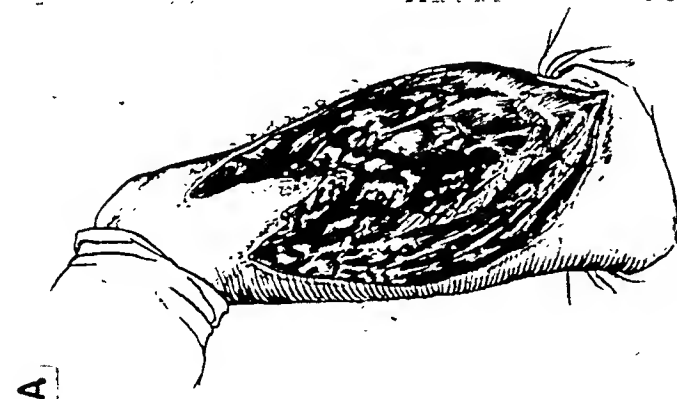
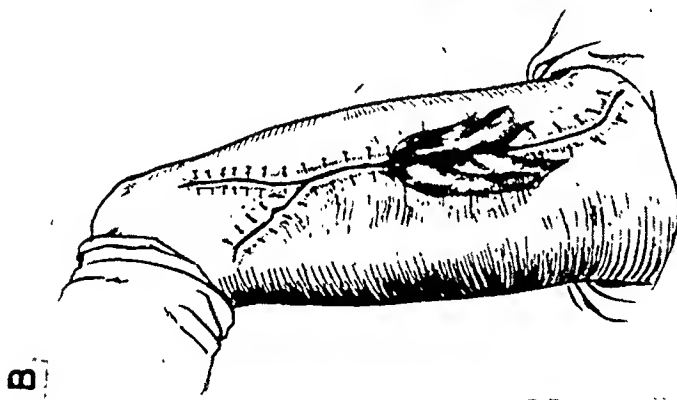
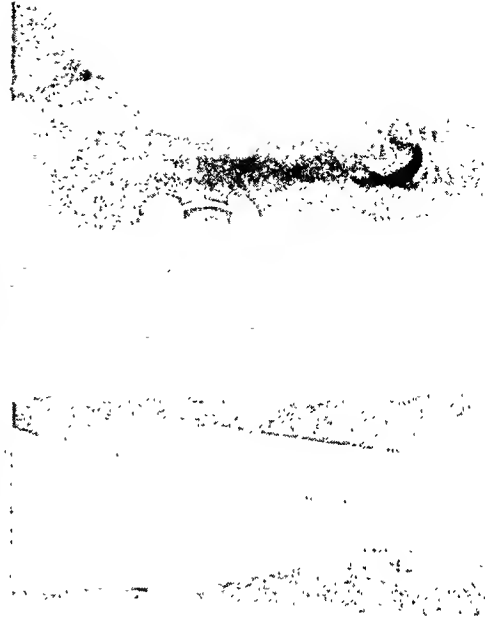
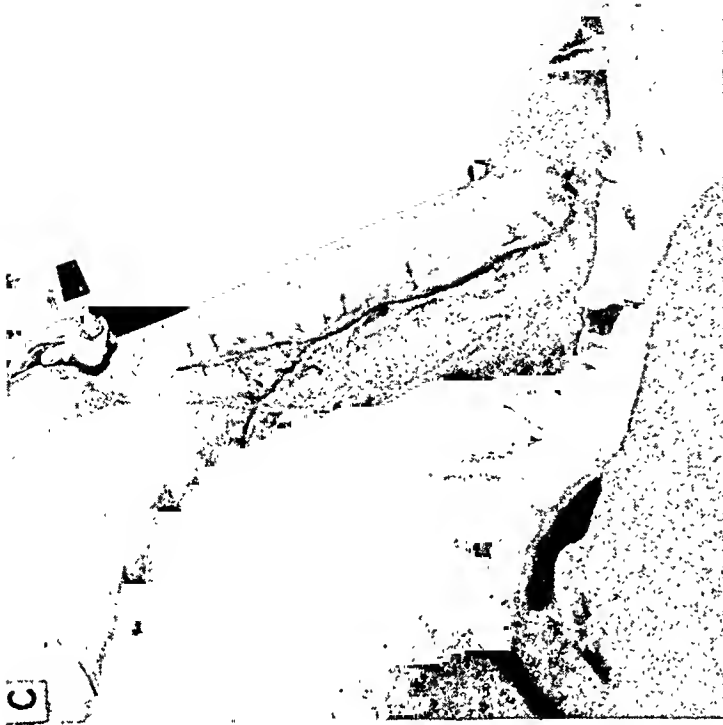


PLATE V.—Case 6: A. Drawing of the huge wound as it presented itself at operation.

B. Drawing of the partial closure with fine-mesh gauze drainage to residual dead space.

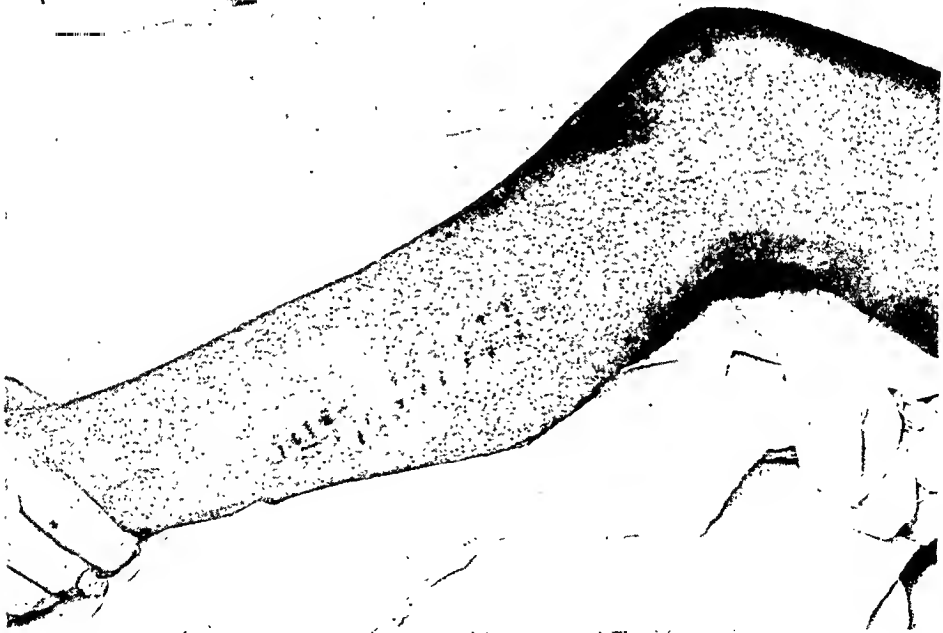
C. In two-wire skeletal traction on the Ward 26, October, 1944. Wound healing is progressing satisfactorily.

D. 17 November, 1944, one month postoperative, complete wound healing has been obtained.

E. Roentgenograms, 24 October, 1944, showing adequate apposition and good alignment. This reduction was maintained until bony union occurred. Note the "lifting" of the distal fragment into apposition in the lateral view.

PLATE VI

A



B

PLATE VI.—Case 7: A. 15 July, 1944. The former defect which has filled with granulations, without sinus to bone.

B. 15 July, 1944. The healed operative incision for the plating of the fibula.

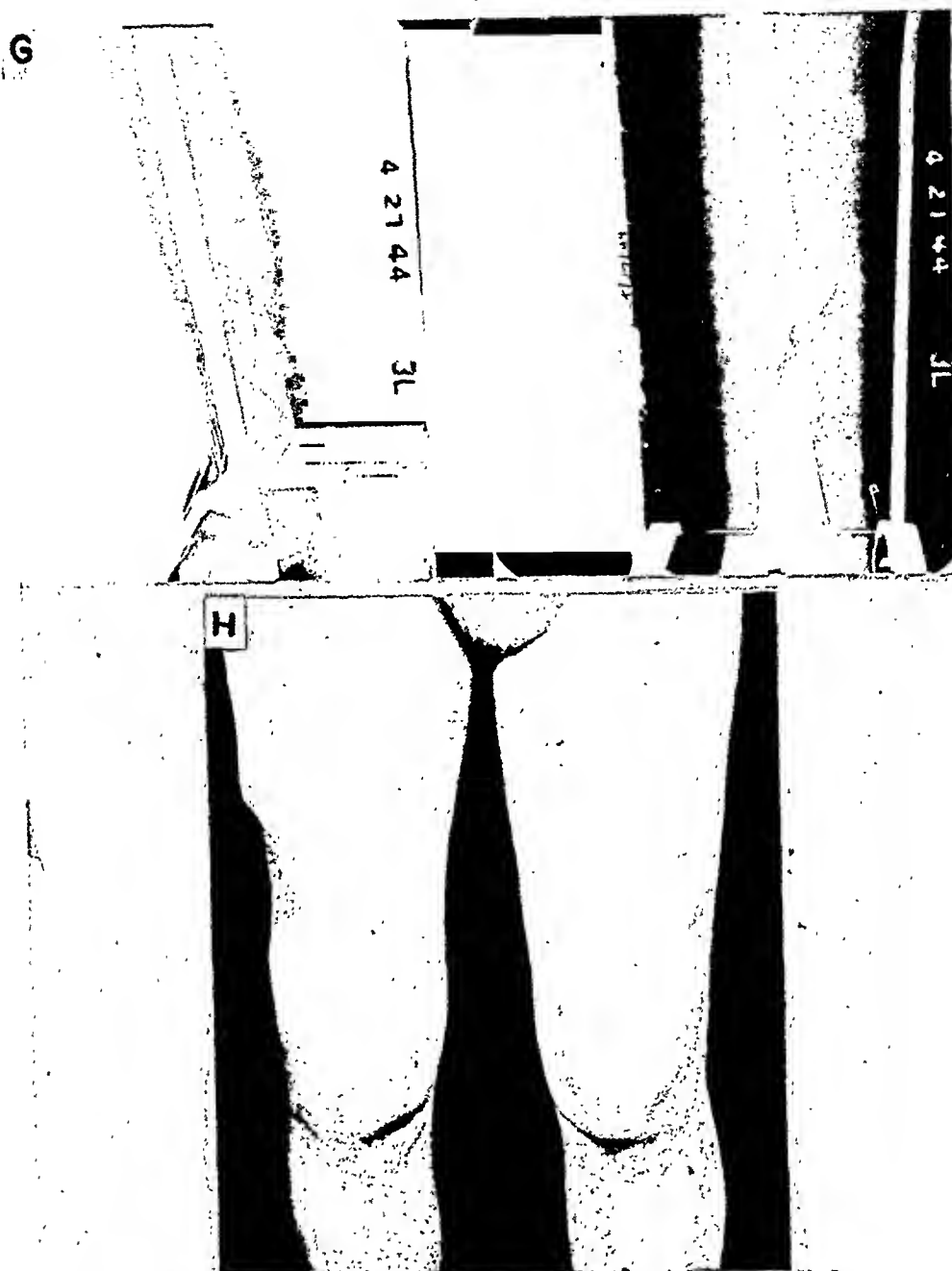


PLATE VII.—Case 8: A. Compounding wounds of the right thigh at reparative surgery, 9 April, 1944.

B. The internal fixation by four screws. Minimal periosteal stripping was required.  
C. Partial closure and loose packing of the dead space, with dependent drainage through a separate incision in the posterolateral fascial plane.



PLATE VII (CONCLUDED)



D. Sutured and drainage wounds are firmly healed and the dead space has filled with granulations, without sinus to bone. 6 July, 1944.

E. Roentgenograms of right femur made postoperative.

F. Left lower extremity in two-wire traction showing the healed anterior thigh wound. The posterior wound was also healed. 6 July, 1944.

G. Roentgenograms of left femur in two-wire traction.

H. The patient fully ambulatory with all wounds healed and 90 degrees knee flexion (excellent for lower third battle fractures) in early 1945.



PLATE VIII



PLATE VIII.—Case 6: A. Lateral wound in operating room 30 October, 1944.

B. Medial wound in operating room 30 October, 1944. Note large blood clots in the wound.

C. Sutured lateral wound at reparative surgery 30 October, 1944.

D. Grafted medial wound 30 October, 1944.

E. A. P. and lateral views of fracture in plaster. Approximately one-inch bone deficit has been overcome by the wire loop fixation.

# COMPOUND BATTLE FRACTURES

PLATE IX

A



B

PLATE IX.—Case 10: A. The united fracture of the humerus in July as shown roentgenologically. The humerus was shortened about one and one-half inches at reparative surgery to obtain contact of fragments.  
B. The healed grafted area over the humerus. The graft had been performed through a large window in the spica, hence, the raw area on the chest had not been grafted.

## PLATE X

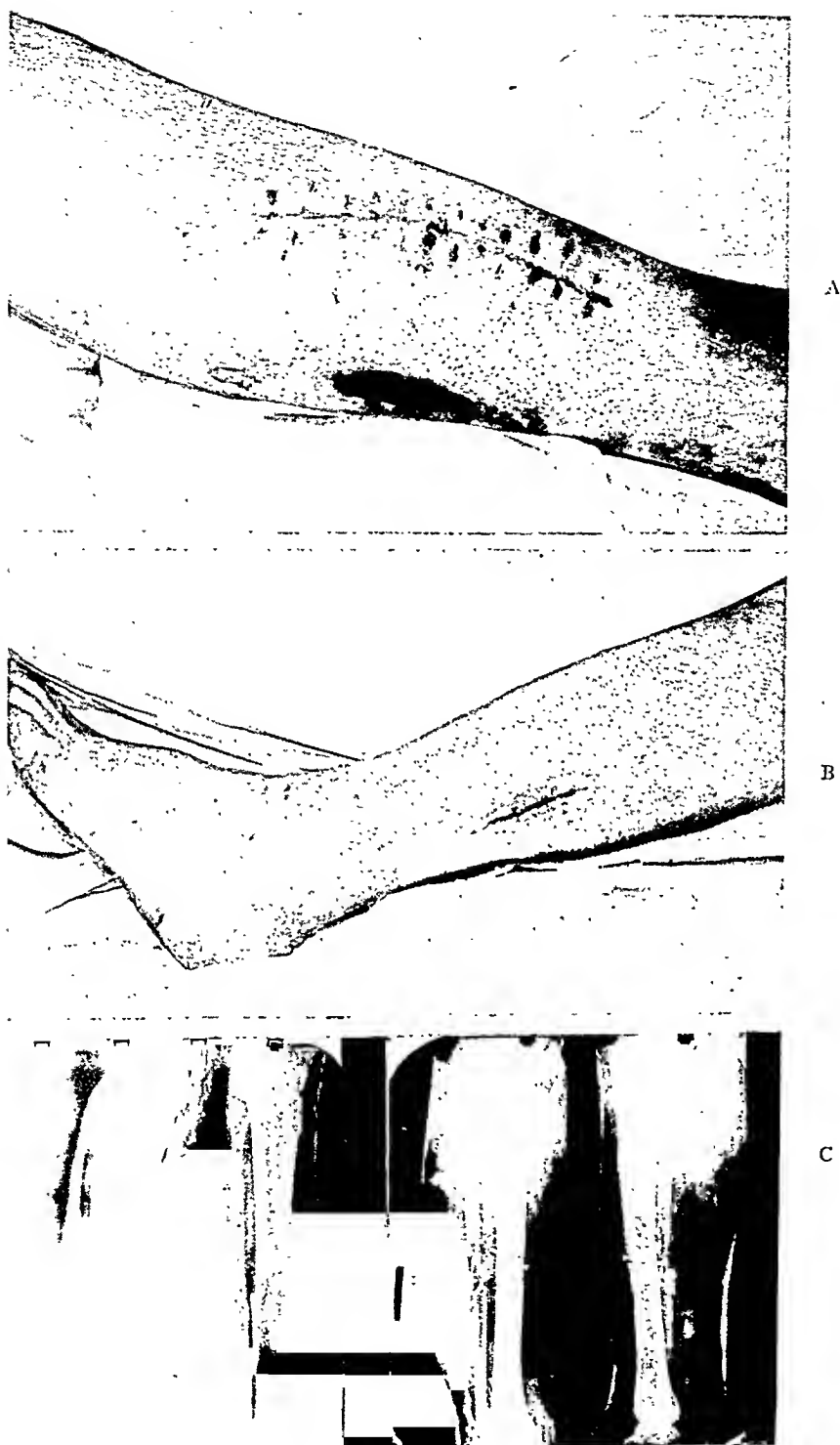


PLATE X.—Case 11: A. 15 July, 1944, four weeks after reparative surgery. Healed sutured wound over the tibia and the granulating relaxing incision. The latter might have been split-skin grafted.

B. The healed lateral wound through which drainage was established for a few days.

C. Roentgenograms made pre- and postoperative. The upper screw missed the drill hole in the distal cortex.

# COMPOUND BATTLE FRACTURES

PLATE XI



PLATE XI.—Case 12: A. Exposure of massive wound, with thigh in the "90-90-90" operative position. Note the projecting bone in wound.  
B. Fracture stabilized by multiple screw fixation, with no additional periosteal stripping.  
C. Partial wound closure and drainage of residual dead space with dry fine-mesh gauze. The sutured areas possibly represent surgical extensions of the wound for adequate exposure. The remaining raw area probably represents the skin loss at the time of wounding.

PLATE XII

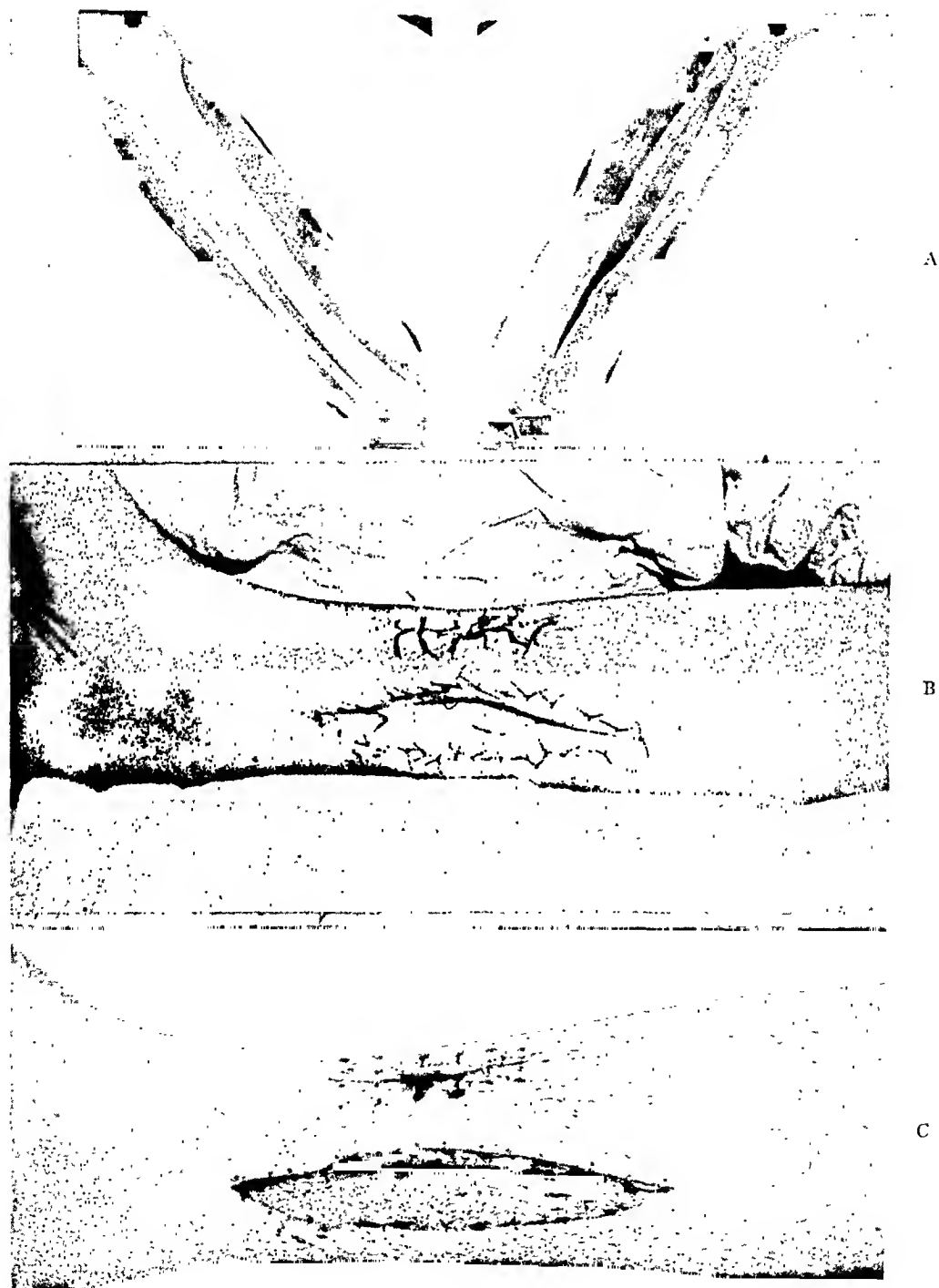


PLATE XII.—Case 13: A. Roentgenograms made at the Base Hospital.

B. Sutured compound wound and skin-grafted relaxing incision of reparative surgery.

C. The healed wound and 95% take on skin graft, two weeks after reparative surgery. Sound wound healing followed shortly. The patient returned to duty in this Theater.

# COMPOUND BATTLE FRACTURES

## PLATE XIII

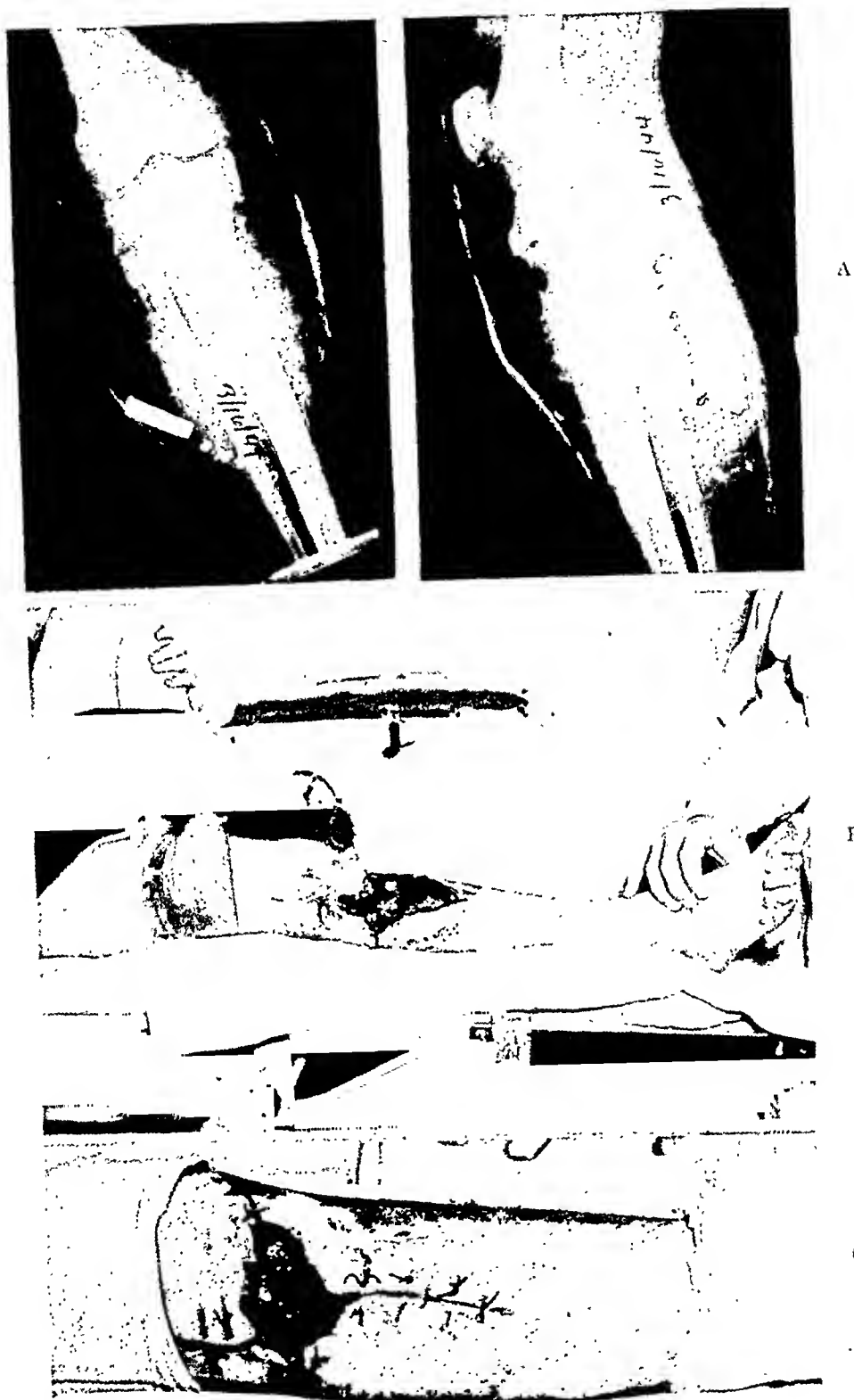


PLATE XIII.—Case 14: A. Roentgenograms made 16 March, 1944.

B. The leg wound in the operating room just prior to reparative surgery. Note the pneumatic tourniquet. Blood loss from upper tibial fractures is usually severe.

C. The healed sutured projections of the wound and the clean fracture cavity on 23 March, 1944. Sutures were removed, the cavity loosely filled with dry fine-mesh gauze and a plaster encasement applied, anticipating no wound disturbance for several weeks.

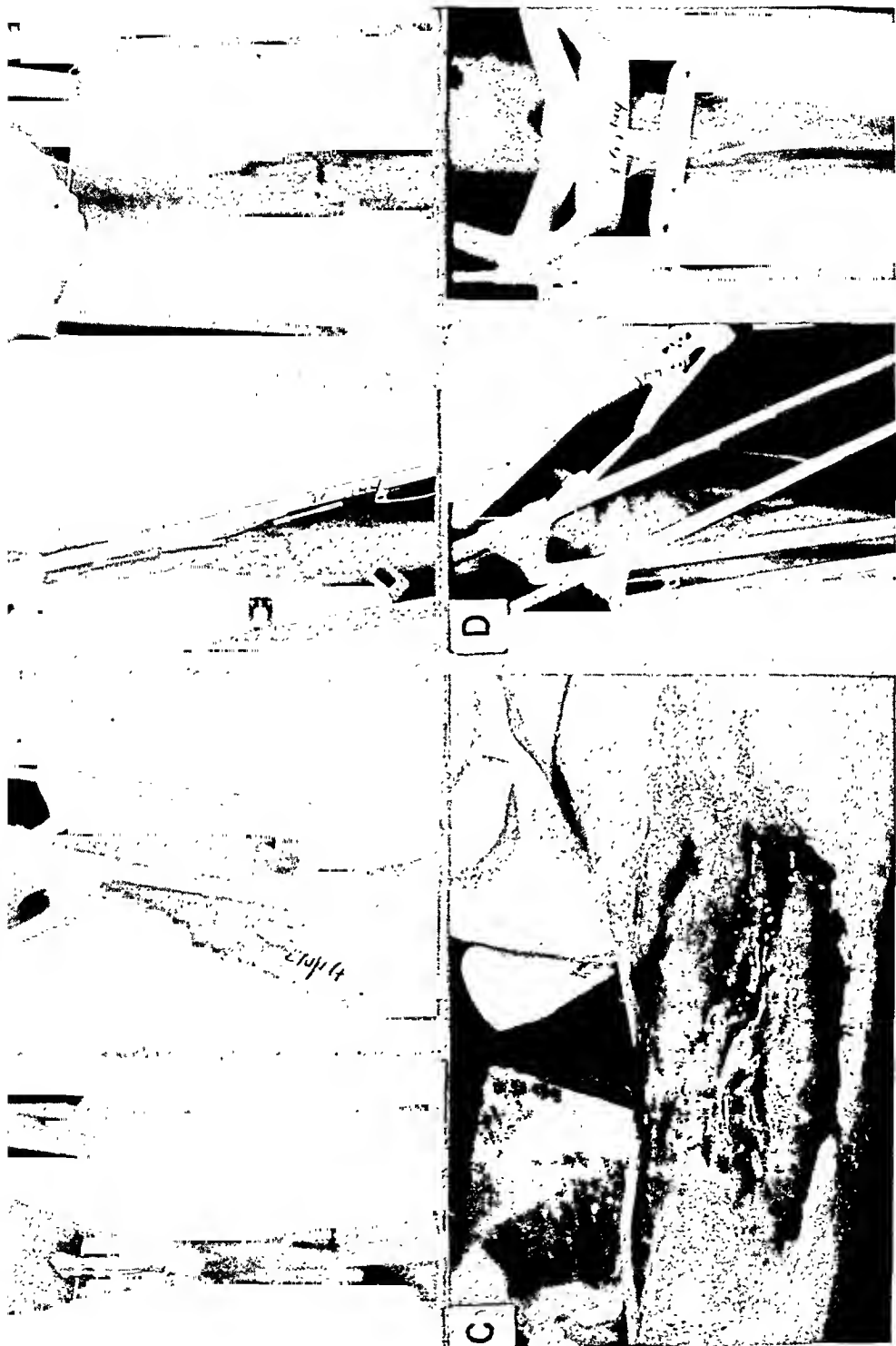


PLATE XIV.—Case 15: A. A. P. and lateral views of the femoral fracture in skeletal traction on 4 February, 1944. Improved reduction was obtained later.

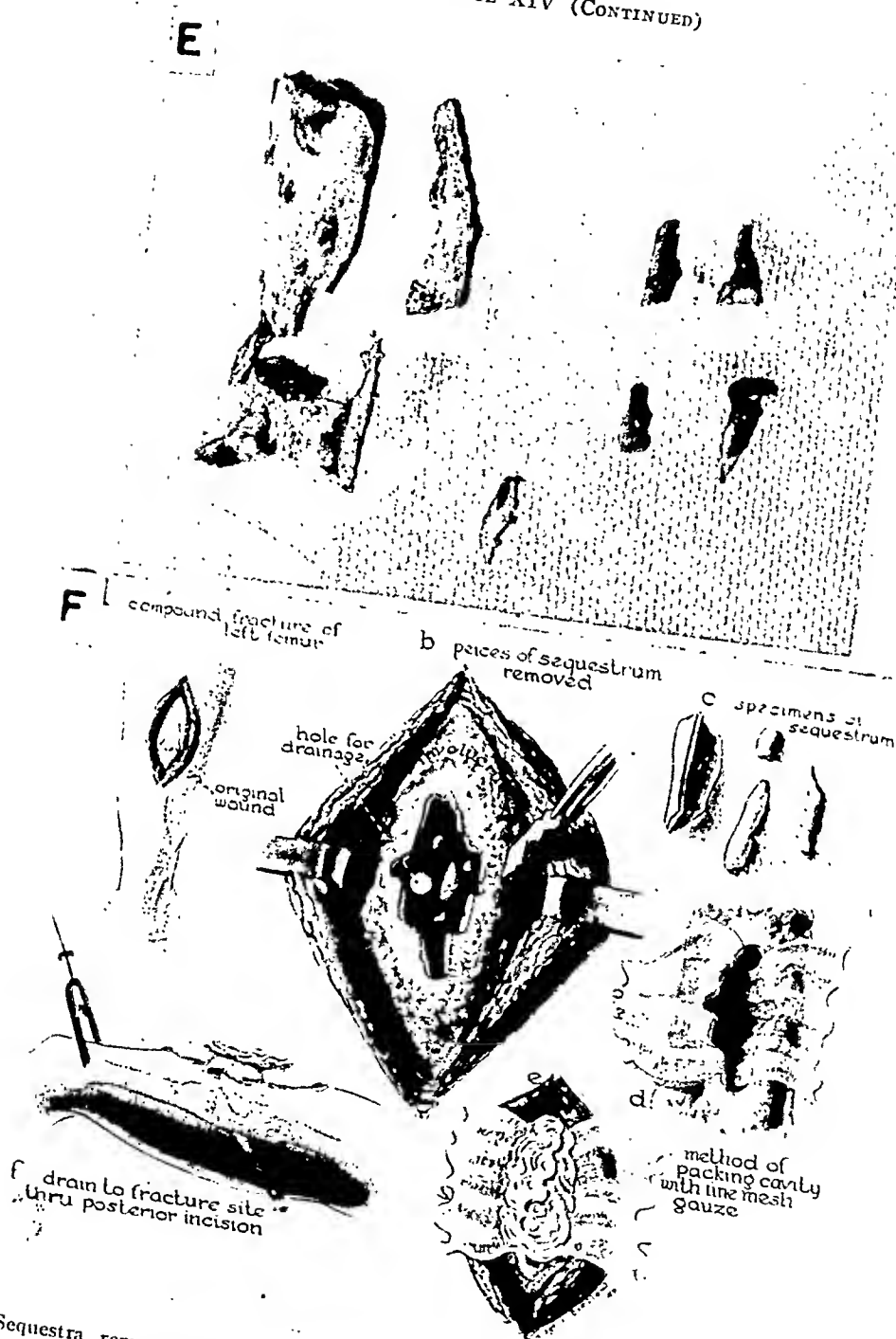
B. A. P. and lateral views 27 March, 1944, showing the partially united fracture with massive sequestrum formation.

C. The large raw anterior thigh wound on 6 April, 1944. The fracture site was open and pus puddled in the depths of the wound.

D. A. P. and lateral views of fracture of the tibia.

# COMPOUND BATTLE FRACTURES

## PLATE XIV (CONTINUED)



E. Sequestra removed from the femur (left) and tibia (right), at operation on 6 April, 1944.  
F. Drawings of the reparative surgery on the femur.



## ILLUSTRATIVE CASE REPORTS\*

**Case 1.—*Diagnosis:*** Penetrating wound of left knee joint, with fracture of medial femoral condyle, incomplete.

***Wounded:*** July 1, 1944, 2100 hours, by high explosive shell fragment which embedded in the medial femoral condyle through the articular surface.

***Initial Surgery:*** July 2, 0400 hours, time-interval, seven hours. Through a two-inch arthrotomy incision, the foreign body was removed, the joint cleaned and the synovia and capsule closed. Penicillin was instilled into the joint and given systemically. A plaster encasement was used for immobilization.

***Reparative Surgery:*** Soon after admission to the Base, wound and joint sepsis was found to be established. Maggots crawled from the joint. The joint was reexplored and a piece of khaki cloth was found buried in the defect in the femoral condyle. Removal of it and devitalized cartilage followed by lavage, joint closure, local and systemic penicillin and immobilization in a hip spica, produced a subsidence of the infection. A late follow-up, April 5, 1945, revealed 90 degrees of painless motion at the knee and all wounds healed.

**COMMENT:** Incomplete initial surgery allowed foreign material to remain. Established sepsis indicated a surgical approach. At wound revision, the khaki cloth and remaining devitalized cartilage were removed, permitting indicated reparative surgery. The completion of excisional surgery soon after admission to the Base Hospital is the keystone of the plan of management.

**Case 2.—*Diagnosis:*** 1. F. C. C. left tibia, upper half. 2. F. C. C. of right femur, upper third (not here considered).

***Wounded:*** February 18, 1944, 0800 hours, by high explosive shell fragments which penetrated the left leg fracturing the tibia.

***Initial Surgery:*** February 18, 1944, 1030 hours. Time-interval, 2.5 hours. Débridement, vaselined gauze dressing and a plaster encasement.

***Reparative Surgery:*** The primary encasement was changed soon after admission and again on March 13, 1944, when it was noted that the drainage was purulent and foul-smelling. An incipient osteomyelitis was thought to be present. On March 30, 1944, the wound and fracture were explored. Several dead unattached indriven fragments of bone were removed. The wound was loosely filled with fine-mesh gauze and an encasement applied. On May 1, 1944, at change of encasement, the wound was clean, there was no foul drainage, and there was clinical evidence of bony stability.

**COMMENT:** Totally detached bone fragments are devitalized tissue that should be removed at initial surgery. Wound revision as the primary step in reparative surgery insures the adequacy of initial surgery. If this fracture site had been explored on admission to the Base, a septic tibia might have been prevented.

**Case 3.—*Diagnosis:*** F. C. C. left femur and patella.

***Wounded:*** February 16, 1944, 1045 hours, by a high explosive shell fragment at Anzio, Italy.

***Initial Surgery:*** February 16, 1944, 2320 hours. Time-interval, 1235 hours. All wounds débrided and metallic foreign body removed from the left knee, 1.5 hip spica applied. He was evacuated to the Base on February 19, 1944, by L. S. T.

\* The reported cases were managed by the staffs of Forward and Base Hospitals of the Mediterranean Theater of Operations. It is regretted that because of insufficient information adequate acknowledgment cannot be given to the surgeons who produced the splendid results. The photographs and artist's drawings were produced by detachments of the Museum and Medical Arts Service.

## COMPOUND BATTLE FRACTURES

*Reparative Surgery:* On February 22, two days after admission to the Base Hospital, exposure of the wound revealed incomplete initial surgery, requiring further excisional surgery. The wound was left open. Skeletal traction was instituted.

On March 14, 21 days after wound revision, he appeared sick and washed-out, and had a continuous low grade fever. The fracture site was visible through a gaping lateral wound. Skeletal traction had failed to obtain fracture reduction. Roentgenograms showed the fracture in distraction, and the seat of a gas abscess. Three thousand cubic centimeters of blood had been administered in the Base Hospital. Operation March 15, 1944: An abscess in the posterolateral plane of thigh, pocketing in the proximal portion, was incised and drained. Totally loose bone fragments were removed, and the fracture was fixed in reduction by a bone plate. After excision of the old wound edge and granulation tissue, the exposed bone, including the fracture site, was covered by partial wound closure. The fracture site and fascial plane were adequately drained by the remaining gaping incision. Two thousand cubic centimeters of blood were given on the day of surgery and penicillin therapy in adequate dosage was instituted. On March 21, 1944, six days later, the wound was found to be clean and was sutured over a Penrose drain emerging at its proximal most dependent portion.

Postoperative course was not eventful. The drain was removed on the seventh postoperative day. A minimal amount of purulent drainage continued intermittently for several weeks. On May 2, 1944, there was no drainage site. A small sequestrum was suggested by late roentgenograms. The patient was evacuated to the Zone of Interior in a plaster encasement in mid-May.

In the Z. of I., solid bony union in anatomic alignment and wound healing followed. There was some absorption about one screw, therefore, the metal was removed. The wound of this procedure healed *per primam*.

**COMMENT:** This septic fracture developed following inadequate initial surgery. The fracture site was the seat of dead space and gas abscess formation. Drainage of the septic process by a lateral wound had been inadequate and a pocket of pus had formed in the posterior proximal thigh. At reparative surgery, sequestra were removed and the dead space of an unreduced fracture was obliterated. The fracture was stabilized in reduction and sufficient wound closure was done to cover all exposed bone. The wide-open posterior wound provided dependent drainage for the residual dead space which was further reduced by the staged closure six days later.

By reparative surgery, sepsis was controlled, the unreduced fracture was stabilized, and bone and wound healing were obtained.

**Case 4.—Diagnosis:** F. C. C. of femur.

*Wounded:* March 10, 1944, 1500 hours, by a high explosive shell fragment which penetrated the left thigh medially, fracturing the femur in the midthird.

*Initial Surgery:* March 10, 1944, 1900 hours. Time-interval, four hours. Débridement and removal of foreign bodies, loose fine-mesh gauze drain and dressing and plaster encasement.

*Reparative Surgery:* On the 19th of March, nine days after wounding, and two days after admission to the Base Hospital, the fracture was approached through a posterolateral incision, passing between the vastus lateralis and the biceps femoris, and stabilized in reduction by a bone plate. An additional screw was inserted through the compounding medial wound. The compounding wound was closed without drainage. The operative approach was closed over a soft Penrose drain. The extremity was placed in skeletal traction in a Thomas splint and Pierson attachment. The drain and sutures were removed on the tenth postoperative day. Healing was excellent, and the drainage area was dry on April 13, 1944. Beginning about April 1, 1944, active and passive knee

motion were permitted and quadriceps exercises were encouraged. In mid-April a 1.5 hip spica was applied for transportation to the Zone of Interior. The fracture went on to union and the wound remained healed. The range of knee motion by early 1945 was practically normal. In March, 1945, he returned to duty in a motor pool at a large General Hospital.

**COMMENT:** A standard anatomic plane approach was used, which permitted the bone exposed by surgery to be covered by healthy soft parts and also permitted dependent drainage. The fracture was anatomically reduced and stabilized, which permitted the necessary handling of the extremity for the removal of drain and sutures. The procedure permitted early knee joint motion and quadriceps exercises. The patient was evacuated to the Zone of Interior approximately one month after wounding. Treatment of the fracture by skeletal traction would probably have given adequate reduction but joint exercises would have been delayed and approximately three months hospitalization would have been required in a busy Theater of Operations.

**Case 5.—*Diagnosis:*** F. C. C. right tibia and fibula.

***Wounded:*** March 27, 1944, 0500 hours, by high explosive shell fragments penetrating right leg (also injuries of other extremities) fracturing the tibia and fibula in the midthird.

***Initial Surgery:*** March 27, 1944, 0900 hours. Time-interval, four hours. All wounds débrided, foreign bodies removed, sulfa crystals, vaselined gauze dressing and plaster encasement.

***Reparative Surgery:*** On admission, March 31, 1944, his hematocrit was 22. Twenty-four hundred cubic centimeters of blood were given over a three-day period. At operation, April 3, 1944, anterior wounds over a fracture were connected. An unsuccessful effort was made to fix the fracture by multiple screws. Then periosteum over a long middle fragment was stripped and a long plate was applied anteromedially, stabilizing the fracture. Two posteromedial wounds were connected to form a relaxing incision, allowing closure of the operative wound. However, the latter failed to heal completely. The center of the incision opened exposing one inch of plate. There was no evidence of wound sepsis but simply failure of healing due to mechanical factors. At his last plaster change in this Theater in mid-May, the wound was clean but about .75-inch of plate was exposed. Following removal of the metal and several sequestra, in the Zone of Interior, at which time the fracture was firmly united, the wound healed and function of the extremity was resumed.

**COMMENT:** In retrospect, the fractured tibia might have been adequately stabilized by plating the fibula or treated by encasement traction, thereby avoiding periosteal stripping and the placing of metal at a point where it interfered with closure of soft parts over bone. The anteromedial surface of the tibia is not a good location for the plate if there is any question of wound healing. The wounds in this case determined that the location of the incision was over the site of the metal.

**Case 6.—*Diagnosis:*** F. C. C. femur, junction M/3 and L/3.

***Wounded:*** September 28, 1944, by small arms fire.

***Initial Surgery:*** October 1, 1944. Time-interval, 60 hours. Extensive excision of devitalized muscle with established sepsis was necessary in the posterolateral thigh through a huge, jagged wound. Vaselined gauze dressing and 1.5 hip spica.

***Reparative Surgery:*** On October 17, 1944 (delayed for tactical reasons), the encasement was removed, a K-wire was inserted in the tibial tubercle and the extremity placed

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in the 90-90-90 operative position. The contour and location of the fracture plus the delay in definitive fracture management might have been considered an indication for rigid internal fixation. However, wound exploration revealed *no exposed bone* and extensive periosteal stripping would have been necessary for fixation. Therefore, skeletal traction was selected, using the tibial wire for traction and a supracondylar wire for lift. The huge wound was partially closed with good drainage. A snug pressure dressing was applied.

**COMMENT:** The disadvantages of internal fixation in compound fractures outweighed the advantages, therefore, it was not employed. To have extensively stripped periosteum would have recompounded the fracture, risking bone sequestration. The result justified the judgment.

**Case 7.—*Diagnosis:*** F. C. C. of tibia and fibula, left.

***Wounded:*** May 24, 1944, by high explosive shell fragment which penetrated the medial surface of the left leg midthird fracturing both bones.

***Initial Surgery:*** Not recorded but apparently routine.

***Reparative Surgery:*** At reparative surgery, May 26, 1944, several totally loose fragments of a badly comminuted tibia were removed through the compounding wound. The transverse fracture of the fibula was plated through a separate operative approach, thereby stabilizing the fractured tibia in adequate reduction. The operative wound was sutured but muscle and skin loss precluded suture of the compounding wound. It was filled with fine-mesh gauze and an encasement applied for Orr treatment. The sutured wound healed and the medial wound granulated to complete healing before evacuation to the Zone of Interior in mid-July.

The wound remained healed but union of the fracture was delayed (bone loss). Because wound healing had been achieved early, reinforcing bone grafting was carried out as soon as the indication could be determined. The fracture is now solidly united in full length and alignment.

**COMMENT:** Wound revision as the primary step of reparative surgery of compound fractures revealed totally loose bone fragments. Fibula plating converted for practical purposes the fracture of both bones of the leg into a fracture of only the tibia. The character of the defect of the wound of injury precluded closure. Therefore, the Orr method was employed with good results. The excellent reparative surgery permitted early and complete reconstructive surgery.

**Case 8.—*Diagnosis:*** F. C. C. of the femur, bilateral.

***Wounded:*** March 26, 1944, 0300 hours, by machine gun bullets perforating each thigh, fracturing each femur about the junction of the middle and lower thirds.

***Initial Surgery:*** March 26, 0930 hours. Time-interval, 6.5 hours. The wounds of entry and exit were incised and the bullet tracks débrided of the devitalized tissue. The wounds of the left thigh were not extensive, but there was severe muscle damage of the right thigh which created a loss of continuity of the vastus lateralis muscle. Considerable muscle was necessarily excised.

***Reparative Surgery:*** On April 9, 1944, three days after admission to the Base Hospital, and after 1,500 cc. of blood replacement, reparative surgery was carried out on both femurs. The right femur was reduced and stabilized by multiple screw fixation, through the compounding wound, enlarged by an incision distally. The size of the defect was reduced by as much closure as possible, which placed soft parts over the metal and most of the exposed bone. The remaining cavity was loosely filled with fine-mesh gauze. In addition, dependent drainage was established through the postero-

lateral plane. The compounding wounds on the left were sutured and dependent drainage was established. Both drains were removed on the eighth postoperative day.

Both extremities were placed in skeletal traction—that on the right to protect the internal fixation, permit early joint motion and provide access to the wounds for necessary dressings—that on the left, for definitive fracture reduction. The sutured portion of the right thigh wound healed and the defect slowly filled with granulations. It was necessary to use two-wire skeletal traction on the left femur but union in excellent reduction was obtained and the wounds healed. A late follow-up observation on March 23, 1945, reveals the fracture firmly united, all wounds healed and about 90 degrees of motion in each knee.

**COMMENT:** Multiple screw fixation of the right femur produced anatomic reduction and alignment with minimal periosteal stripping. The partial closure covered practically all exposed bone, but it was necessary to resort to a method of loose packing and infrequent dressings to permit granulations to fill the defect. The dependent drainage established on the right was considered important, but that on the left might have been omitted. In fact, the surgeon performing the operation stated that his drain did not reach the fracture site.

**Case 9.—Diagnosis:** F. C. C. humerus with bone loss.

**Wounded:** October 21, 1944, 1200 hours, by high explosive shell fragment perforating arm and fracturing the humerus.

**Initial Surgery:** October 21, 1944. Excision of devitalized tissue. Four centimeters of humerus were missing; the brachial artery, median and ulnar nerves were exposed and found intact; the radial nerve was severed. Because of danger of injury to the artery by the sharp fragment ends, a wire loop was used to overcome the 4 cm. gap and hold the fragments in approximation. The wounds were dressed and a Velpeau plaster utilized as transportation splinting.

**Reparative Surgery:** On October 30, 1944, the fracture site was inspected, the wounds cleaned of blood clots and a few tags of muscle excised. The lateral wound was closed. The medial wound was grafted. A slip of fine-mesh gauze extended through the grafted medial wound to dead space about fracture site. A pressure dressing was applied and a shoulder spica used for immobilization. On November 17, 1944, at change of plaster, the lateral wound was solidly healed, a 75 per cent take of the graft was seen. The fracture site appeared to have sealed-off, and there was no opening to bone.

**COMMENT:** This case illustrates an excellent use of internal fixation at initial surgery and justifies a policy of permitting the procedure in Forward Hospitals on definite indications usually to protect vessels or nerves. If the wire loop had not been used in the Evacuation Hospital, it would have been placed in the Base to overcome the bone deficit. By closure and graft, plus a partial open wound with fine-mesh gauze for drainage the skin defects were minimized and the compound fracture soon became sealed-off.

**Case 10.—Diagnosis:** F. C. C. right humerus.

**Summary:** The patient was wounded on April 8, 1944, by a high explosive shell fragment which produced a massive soft-tissue injury of the right arm and a comminuted fracture of the humerus. A radial palsy was present. Initial surgery was the routine. At reparative surgery in the Base, several totally loose bone fragments were removed, producing a one-inch segmental bone defect, which was overcome by the use of a wire loop to hold the major fragments in contact. The radial nerve was visualized intact. The muscles of the arm were sutured over the exposed bone with

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fine-mesh gauze drainage from the fracture site and a shoulder spica applied. After a granulating bed had formed, the skin defect was covered by a split-skin graft on May 20, 1944. Complete healing of the compounding wound was obtained and the fracture united prior to evacuation to the Zone of Interior in July. There was partial recovery of radial power.

**COMMENT:** At reparative surgery, potential sequestra were removed and bony contact predisposing to union was obtained by wire loop internal fixation. Muscle closure over bone obtained the major objective of wound closure. Fine-mesh gauze drainage was used for a few days. Delayed skin grafting completed the reparative surgery.

**Case 11.—Diagnosis:** F. C. C. of tibia and fibula.

**Wounded:** June 8, 1944, by high explosive shell fragments penetrating the left leg, fracturing the tibia and fibula.

**Initial Surgery:** Not recorded but presumably routine.

**Reparative Surgery:** June 17, 1944, four days after admission to Base Hospital, exposure revealed two clean wounds, one anteromedial exposing the fracture site, the other posterolateral. The tibia was stabilized in reduction by multiple screw fixation through the anteromedial incision, which was then sutured after a posteromedial relaxing incision. Drainage was established through the posterolateral injury wound. The sutured wound healed and the two posterior wounds were almost healed, with no sinus formation, when he was evacuated to the Zone of Interior in mid-July.

In the Zone of Interior the fracture united in anatomic alignment and the wounds remained healed. He is now on duty in a General Hospital.

**COMMENT:** Multiple screw fixation permitted stabilization of the fracture in anatomic reduction without additional periosteal stripping and without excessive intrawound trauma. The relaxing incision permitted the sliding of a skin flap and closure of the anterior wound without tension over the exposed bone, thereby attaining a major objective of reparative surgery of compound fractures.

**Case 12.—Diagnosis:** F. C. C. femur.

**Wounded:** October 26, 1944, 1200 hours, by high explosive shell fragment, which fractured the left femur in its midthird and produced an extensive soft-tissue wound.

**Initial Surgery:** October 26, 2200 hours. Time-interval, 10 hours. Excision of devitalized tissue; vaselined gauze dressing and Tobruk splint.

**Reparative Surgery:** November 1, 1944, six days after wounding, and three days after admission to the Base Hospital, during which time 1,500 cc. of whole blood were given, the femur was stabilized by multiple screw fixation, and the large gaping wound was partially closed. The wound was dressed with fine-mesh gauze and the extremity placed in skeletal traction. November 15, 1944, the sutured wounds were healed. The fracture site had sealed-off so the remaining defect was skin grafted.

**COMMENT:** Multiple screw fixation stabilized the fracture in anatomic reduction and permitted handling of extremity for subsequent management of the extensive soft-part wound. Partial skin closure reduced the size of the defect. This is an excellent example of reparative surgery of a severe battle compound fracture. Reduction in skeletal traction is difficult to maintain when the surrounding soft tissue loss is extensive.

**Case 13.—Diagnosis:** F. C. C. right tibia lower third.

**Summary:** The patient was wounded by a fragment following a land-mine explosion which penetrated the anteromedial surface of the right leg, fracturing the tibia. At

initial surgery, the wound of entry was débrided and a foreign body removed. At reparative surgery in the Base Hospital a long posteromedial relaxing incision permitted closure of the compounding wound covering the exposed fracture site. The defect created by the relaxing incision was covered by split-skin graft. Complete wound healing was obtained.

**COMMENT:** The exposed fracture site was covered with soft-parts facilitating their revascularization, preventing contamination at changes of plaster and providing healthy skin over the bone.

**Case 14.—Diagnosis:** F. C. C. tibia, upper third, right.

**Wounded:** March 8, 1944, 1745 hours, by high explosive shell fragment which perforated the proximal leg, comminuting the tibia.

**Initial surgery:** March 8, 1944, 2130 hours. Time-interval, 3.75 hours. The wounds of entry and exit were connected to provide exposure for débridement and arrest of severe hemorrhage from the cancellous bone which required tight packing.

**Reparative Surgery:** March 16, 1944, the day after admission to the Base Hospital, the fracture site was cleansed, the irregular wound was sutured so as to cover, as best as possible, the exposed bony cortex, tips of denuded fragments remaining exposed were ronguered away, the wound was dressed with fine-mesh gauze and an encasement applied. The patient remained on his side, facilitating dependent drainage. At change of encasement a week later the wound was clean and "dry" and healing of the closed wounds permitted removal of the sutures. The cavity remaining was loosely filled with fine-mesh gauze and an encasement applied. The latter was changed in late April, at which time the wound was clean and partially filled by healthy granulations. No bony cortex was exposed. He was then evacuated to the Zone of Interior.

**COMMENT:** The partial wound closure covered, protected and aided in preserving the exposed cortical bone and reduced the size of the wound defect. Initial surgery was excellent, so no further excisional surgery was necessary. The character of the defect including the loss of tissue and residual dead space dictated the Orr method of treatment.

**Case 15.—Diagnosis:** (1) F. C. C. left femur, midthird. (2) F. C. C. left tibia, upper third.

**Wounded:** January 18, 1944, 1500 hours, by high explosive shell fragments penetrating left leg and thigh anteriorly, fracturing the tibia and femur.

**Initial Surgery:** January 18, 1944: Débridement of all wounds, removal of foreign bodies, application of a 1.5 hip spica.

**Early Base Care:** January 30, 1944, 12 days after wounding, the wounds were dressed, and femoral skeletal traction instituted, with a boot encasement on the leg and foot. The anterolateral wound compounding the femur was extensive, with muscle loss exposing the femoral fragments for several inches. The fracture of the femur united in good position but there was massive sequestration of portions of the major fragments as well as minor comminuted pieces. The thigh and leg wounds continued to drain with no signs of healing but the patient was not toxemic.

**Reparative Surgery:** April 6, 1944, 2.5 months after injury, at operation, the sequestra of the femur were removed, and dependent drainage was established in addition to the open anterior wound. At exploration of the tibia, sequestra of indriven cortical bone in the marrow cavity were removed. Both compounding wounds were loosely filled with dry fine-mesh gauze, and a plaster encasement applied. Twelve days later, at a change of encasement, both wounds appeared clean. The patient remained afebrile, and was evacuated to the Zone of Interior about May 1, 1944.

In the Zone of Interior all wounds were healed by September, 1944. Both fractures were sufficiently solid by December to permit weight-bearing.

COMMENT: There was massive sequestration of bone not covered by soft parts, including part of the major fragments. Wound sepsis of both the thigh and leg wounds persisted because of sequestra. Early reparative surgery by wound closure over exposed bone might have prevented the sequestration of the femoral fragments and by adequate wound revision might have prevented the septic tibial wound. Following delayed reparative surgery, the processes were controlled, and wound and fracture healing were achieved.

DISCUSSION.—The plan of management provides indicated surgery in an effort to achieve the best possible anatomic and functional result in the least practicable period of time. The old concept that surgery in a known infected field would result in failure and possible serious complications is ignored. The success attained varies with the accuracy of surgical judgment and the skill of operative technic. Wound revision is conceived as a meticulous completion of excisional surgery to remove tissue that may harbor infection rather than a meddlesome and traumatizing procedure. Clean, well-drained wounds require little or no revision. Fracture management permits the surgeon to "know" the fracture. The adjustment of fragments under direct vision may be an important step towards obtaining maximum fracture reduction.

Internal fixation of battle fractures is admittedly a controversial subject. It is utilized when its advantages outweigh the disadvantages and is employed frequently at the primary operation of reparative surgery in fractures about joints to permit anatomic replacement of articular surfaces, *e.g.*, condyles of femur or humerus; in fractures of long bones deep in muscle tissue, a situation which favors early reattachment of soft parts, *e.g.*, the femoral shaft and upper radius; in those fractures which experience teaches are difficult to hold in reduction by other means, *e.g.*, olecranon, associated massive soft tissue loss (Case 12), and in fractures with segmental bone loss to achieve contact of fragments in an effort to prevent nonunion. It is to be avoided when the disadvantages predominate, *e.g.*, the tibia, where periosteal stripping is hazardous because the overlying skin is not a sufficiently vascular soft part and where metal may interfere with even skin closure. The surgeon who finds many indications for internal fixation in the management of simple fractures will find many indications in battle fractures, but he must ever be mindful of the hazards of the method. He who uses it as a last resort in simple fractures will use it sparingly in battle fractures. An accurate appraisal of the possibilities of stabilizing the fracture by plating or multiple screws is essential. If the fracture remains unfixed after the metal is placed, the procedure is doomed, as motion at the fracture site will produce absorption about the screws. Experience verifies this conception.

When the indications and advantages are not clear-cut, it is preferable to perform wound closure and attempt fracture reduction by manipulation or traction. If these are unsuccessful, a planned open reduction and internal fixation may be carried out later, perhaps after wound healing. The important point is that poor anatomic results are no longer accepted for fear of



lighting-up infection if they can be prevented by surgical measures performed under good principles.

Reparative surgery has established *delayed* closure over fractures as a logical and surgically sound procedure. Wound closure is conceived primarily to salvage the denuded bone, *protect* the exposed fracture site and *prevent* sepsis; secondarily, it attempts to speed wound healing by the surgical approximation of tissues, thereby minimizing the resultant scar. It does so under the conception that a wide open wound is not essential for adequate drainage if excisional surgery is complete and dead space held to a minimum; that drainage is preferably dependent and that it may be adequately provided in many instances by fine-mesh gauze or rubber wicks emerging through sutured wounds or counterincisions. The theoretic objection that drains to fracture sites are conducive to sinus formation has not been substantiated in this experience. Wound healing, while affected by several factors, is a natural cellular growth<sup>15</sup> provided the wound does not contain dead tissue, strangulating ligatures, dead space, *etc.* Wound closure, in an effort to achieve rapid wound healing, is practiced to the extent to which these qualifying factors may be surgically obviated.

Clinically clean cases on admission to the Base Hospital lend themselves to the full program, with anticipated good results. Of even greater importance, a surgical approach is established for the clinically dirty wounds and for wounds with established sepsis, groups which always were the major problems in war surgery. By judicious application of the surgical principles of reparative surgery, *i.e.*, excision of dead tissue, obliteration or dependent drainage of dead space, pressure dressings, adequate reduction and immobilization of fractures and staged closures, these problem cases may be converted into clean cases, reparative procedures instituted and the objectives of the program achieved.

A thesis of this treatise is the restoration (or preservation) of the periosteal blood supply of the cortex of bone to prevent its sequestration. Indeed, the major problem of the management of battle fractures is the denuded cortex of bone which will surely sequester unless it is rapidly revascularized. In the presence of sequestering bone, wound healing and fracture union are retarded or prevented. If all denuded bone in a battle fracture could be excised, wound healing would come easy, but the price in deformity is prohibitive. Therefore, the problem is the restoration of vitality to denuded bone while at the same time obtaining and maintaining fracture reduction projected towards bony union and the functional restoration of the extremity. The principles of reparative surgery of compound fractures are designed to solve that problem.

#### APPRAISAL OF RESULTS

In a Theater of Operations, statistical results on compound fractures cannot be compiled. End-results are not seen as many cases are evacuated to the Zone of Interior before wound or fracture healing is complete. Multiple

observers in many hospitals compiling tables of results would only confuse the issues. Therefore, conclusions of experienced overseas War Surgeons based upon continuing study and observation must serve to evaluate the over-all program. The consensus of opinion on the reparative program for compound fractures is summarized as follows:

1. Septic patients are few. No deaths, amputations or serious sequelae *resulting from* overzealous reparative surgery have been reported. This refutes the old impression that surgery in an infected field would establish a generalized sepsis.

2. Wound sepsis has been minimized. When it is established following reparative surgery, wound revision is again employed excising or draining the pabulum anticipating staged closure if surgically feasible, rather than await sequestration of the devitalized tissue and risk further local necrosis of living tissues.

3. Fracture reductions are greatly improved as inadequate reduction is not tolerated if it can be improved by nonoperative or operative procedures. Segmental bone deficits forecasting nonunion are rarely accepted.

4. Internal fixation of fractures particularly around joints has restored joint congruity and permitted early joint motion and muscle exercise pointing towards improved functional results.

5. Complete wound healing following suture has been obtained in many cases. In others, the fracture site was rapidly closed-off resulting in, for practical purposes, a simple fracture with skin defects to heal by granulation aided by split-skin grafting. In many cases prolonged drainage from the depths of the wound has been inevitable with any form of treatment, *e.g.*, badly comminuted fractures with many partially detached fragments and with associated dead space. Drainage will persist until the denuded bone has been revitalized or becomes a sequestrum and removed. As sequestration occurs, sinus formation develops and persists. If there is free egress for the drainage, continuing local necrosis is *nil* or at a minimum. Where the sinus is to sequestra that could not be prevented surgically, they must be accepted as a result of the injury. Here, again, the failure of wound healing results from retained dead tissue, the sequestrum, rather than from the invasive action of bacteria *per se*. When the degree of wound healing obtained has not been that anticipated, the result has been attributed to errors in judgment as to what was surgically feasible or to errors in technic. Under the plan of management scar formation, with its effects on future function, has been minimized.

It is regretted that figures are not available on the end-results of fracture and wound healing obtained when metallic internal fixation was used. It is stressed that reduction of the fracture, not the use of internal fixation is the objective. Observation within the Theater and reports from the Zone of Interior indicate that, in a substantial majority, the fractures have united and the wounds have healed. Persistent sinus formation, possibly to metal, possibly to sequestra, is anticipated in a certain percentage of cases. If

union of the fracture in good position occurs and the wound heals after removal of the metal and sequestra in the Zone of Interior, as is anticipated in this group, the result will be considered satisfactory. Any nonunions should be evaluated against the probabilities of nonunion had internal fixation not been used. The over-all results must be evaluated in the light of the problem at hand for which the surgeon chooses internal fixation as a part of reparative surgery. Through arrangements approved by the Surgeon-General and the Surgeon, Mediterranean Theater of Operations, a detailed follow-up study on this group of cases is under way, and will be the subject of a later report.

A comparative appraisal of the reparative program with methods of management previously employed is deemed unessential. It is sufficient that veteran war surgeons who have observed and studied the development and results (as seen in this Theater) of reparative surgery of compound fractures are satisfied that the objectives of the program have been "surrounded and isolated" if not "taken." Further experience with continuing reevaluation of results will undoubtedly produce modifications in the surgical management of these war wounded. Blood and penicillin, the surgical adjuncts, have contributed greatly, possibly their maximum, to the success of the program. However, improved results may be anticipated with perfection of surgery for which there is no substitute in the management of the wounds of war.

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# THE MANAGEMENT OF INTRATHORACIC AND THORACO-ABDOMINAL WOUNDS IN THE COMBAT ZONE

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THOSE CASUALTIES with the most severe wounds of the chest die on the battlefield. With available and intelligent care, most of the remainder may live. Much has been learned concerning management of chest wounds since American forces landed in North Africa in 1942. The Fifth Army campaign in Italy has provided much opportunity for study and improvement. Experience has led to the salvaging of an increasing number of lives. It is the purpose of this paper to discuss the care of chest wounds in the combat zone only. This includes all management from the time first aid is rendered, until after primary definitive surgery has been performed in a field or evacuation hospital, and the patient is ready for evacuation to a base hospital. Statistical data and case reports are used to support important policies and procedures advocated. Personal opinions are based upon the writer's experience as head of a thoracic surgery team in an evacuation hospital in England and North Africa, as surgical consultant to the Second Corps in Tunisia and Sicily, and as surgical consultant to the Fifth Army in Italy. As surgical consultant the writer has had the privilege of doing surgery in some, and of observing the surgery done in all forward hospital installations in Tunisia, Sicily, and Italy. Case reports on all major thoracic wounds admitted to the Second Corps hospitals in Northern Tunisia and Sicily have been studied and case reports on all battle casualty deaths in the Fifth Army hospitals since January 1, 1944, have been available. Frequent visits to base hospitals and thoracic surgery centers to which casualties have been evacuated, and suggestions from the base surgeons have been most valuable. The development of our present methods of management of chest wounds has been accomplished under the able supervision of Colonel Edward D. Churchill, consulting surgeon, M. T. O. U. S. A.

## HOSPITALIZATION

In the Fifth Army, the primary definitive surgery of chest wounds is done either in field or evacuation hospitals. Active divisions are supported by a field hospital unit placed immediately adjacent to the division clearing station. This unit is augmented by two to eight general surgical teams and one shock team from an auxiliary surgical group. The clearing station is usually situated four to ten miles behind the front line. All casualties from the infantry regiments are cleared through this station. It is the triage or sorting point. First-priority cases are carried by litter to the adjacent field hospital, others are evacuated by ambulance to evacuation hospitals, usually situated four to ten miles further back (Diagram). Evacuation hospitals also receive first-priority cases from aid stations of Army units and units which may be closer to the evacuation hospital than to the clearing station.

Field hospitals are prepared to do intrathoracic surgery and to hold patients

postoperatively 10 to 14 days, or longer, as indicated. Roentgenologic facilities, suction machines, bronchoscopes, thoracic surgery instruments, positive pressure anesthesia machines of the same sort as found in evacuation hospitals are now available in these forward units. Blood is supplied from the Base in adequate quantity. Additional nurses augment the nursing staff of the hospital when needed.

Personnel problems have required much study and attention. Each evacuation hospital is supposed to have a thoracic surgeon or general surgeon experienced in traumatic surgery of the chest. Now, each evacuation hospital is so staffed, but this was not true in the beginning. There were not enough thoracic surgeons available to do all the chest surgery in field hospitals. General surgeons had to learn the surgical technic peculiar to intrathoracic surgery. They had especially to learn sound principles of pre- and postoperative management of wounds of the chest. A number of factors contributed to the education of these general surgeons. Their actual experience with thoracic wounds which demanded emergency surgery was most important. In many instances it was possible to place a thoracic surgeon or a thoracic surgical team in a field hospital unit. At times this team attempted to care for most of the chest wounds admitted. Other times, the thoracic surgeon acted as consultant to the general surgeons in their management of chest wounds. In some instances he acted as assistant surgeon at the operation and in other instances he was assisted by the general surgeon. The formally trained thoracic surgeons have contributed much in this educational program. However, they have, themselves, required much education. Some were completely inexperienced in abdominal surgery or had not done abdominal surgery for a number of years. They required the assistance of a good general surgeon to handle properly thoraco-abdominal wounds, which comprise a large part of the first-priority or nontransportable chest cases. The formal training of thoracic surgeons was peculiarly limited to elective surgery of thoracic disease and, except as the basic principles of this experience were pertinent, they were totally unfamiliar with the clinical management of thoracic injury. In the future, if traumatic surgery of the chest is to be well done, in civil life or in time of war, all general surgeons must have training in thoracic surgery. Likewise, if there are to be specialists in thoracic surgery, they must be good general surgeons. It was more than two years after Pearl Harbor before enough general surgeons were trained to care adequately for patients with wounds of the chest in this theater of operations.

Dissemination of knowledge gained by those with early experience, frequent group discussions, medical conferences of the Fifth Army, reports from Base surgeons, suggestions from consultants have all contributed to the improvement in forward thoracic surgery.

A similar program of education has been necessary for the anesthetists. Many lacked training and experience in endotracheal anesthesia for chest surgery. With the coöperation of fully trained and experienced anesthetists and chest surgeons, a large number have been trained to pass endotracheal

tubes, to properly expand the lungs by positive pressure, and to do bronchoscopic aspiration of the trachea and large bronchi. Proper training and experience on the part of the anesthetist is just as important as the training and experience of the surgeon in the management of wounds of the chest.

#### TRIAGE

Early experience demonstrated that some patients were definitely not transportable beyond the division clearing station because of the thoracic or thoraco-abdominal wounds. Later experience has shown that many lives can be saved if even more than the absolutely nontransportable patients are given the benefit of surgery in the field hospital unit which is set-up immediately adjacent to the division clearing station. A study of all battle casualty deaths in evacuation hospitals in Fifth Army in one of the early months of the campaign<sup>1</sup> disclosed that approximately 36 per cent of those dying might have lived had they had surgery in a field hospital. More than one-third of these, or approximately 15 per cent of the entire group, had sucking chest wounds, thoraco-abdominal wounds, or wounds of the chest accompanied by shock or dyspnea. (Case 1 is illustrative.) Corrective action was taken and a larger percentage of the wounded now have surgery in the field hospital unit.

It is now considered desirable that the following types of chest cases be regarded as first-priority and be transferred to the nearest hospital installation for surgery. (In the case of active divisions, this nearest hospital should be a field hospital unit, staffed with auxiliary surgical group teams and situated in close proximity to the division clearing station.)

1. All of those in shock or who have been in shock.
2. All of those with continuing hemorrhage.
3. All sucking chest wounds.
4. Chest wounds in which there is any degree of respiratory difficulty or dyspnea.
5. All thoraco-abdominal wounds.

#### FIRST AID MANAGEMENT OF WOUNDS OF THE CHEST

The first aid management of wounds of the chest is begun by the first member of the medical department to see the patient. This is usually the aid man. The first step is the application of an occlusive dressing to the wound. It has been pointed out<sup>2</sup> that every chest wound should be dressed as though it were a sucking wound, for many not sucking at the time the dressing is applied may begin to suck when the patient changes position or moves an arm. The dressing should consist of a layer of vaselined gauze (if available) next to the skin and a gauze pad, strapped firmly in place with overlapping layers of adhesive. It may be necessary in large open wounds to anchor the gauze dressing to the skin, wide of the wound, with a few sutures. Usually gauze and adhesive properly applied will close the wound tightly enough. Emergency closure of the wound by suture is condemned. Some patients who have had such closures have developed tension

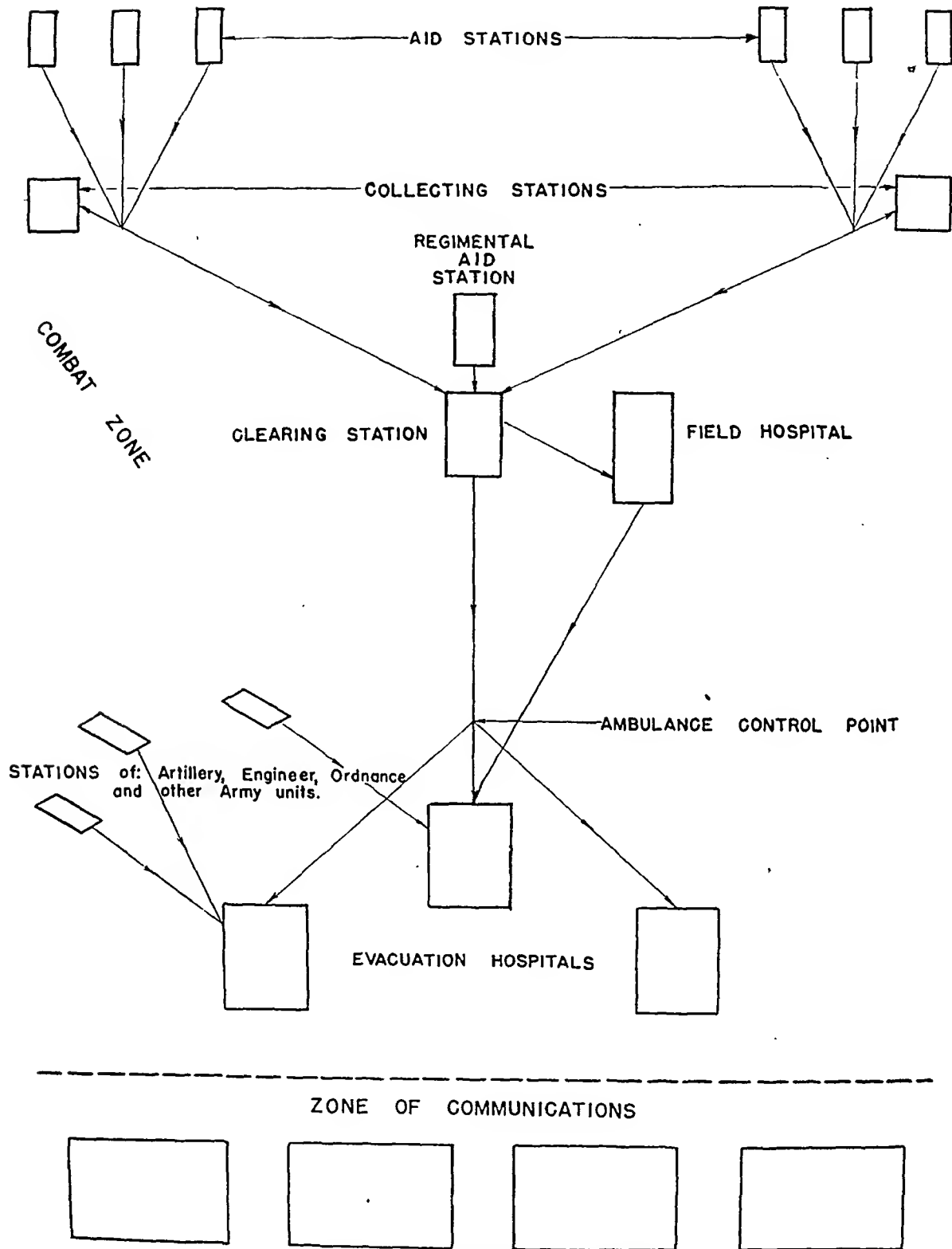


FIG. 1.—Diagram showing line of evacuation of battle casualties.

pneumothorax and died on the way to, or shortly after reaching a hospital. In others, extensive subcutaneous emphysema has resulted. In times of stress in a hospital, a sutured wound may receive no further attention under the assumption that débridement has been done and later on the wound becomes infected and breaks open.

A large pneumothorax or a tension pneumothorax may demand attention in the aid or collecting station. Tension pneumothorax *per se* is rarely seen. A large-bore needle or a small catheter may be inserted in the second interspace anteriorly and fitted with a flutter valve made from a condom, old rubber glove or Penrose drain tubing.

Shock must also be treated. It has not been practical to use whole blood in aid or collecting stations. Its use in the clearing stations is not desirable when the patient can be immediately transferred to a field hospital. The minimum amount of plasma necessary for resuscitation should be administered and further replacement therapy delayed until the wounded man reaches a hospital.

#### PREOPERATIVE MANAGEMENT OF WOUNDS OF THE CHEST IN HOSPITAL INSTALLATIONS

When a patient with a chest wound is admitted to the hospital an immediate, rapid examination must be made to determine (1) the blood pressure and pulse findings; (2) whether the wound is properly dressed and not sucking; (3) the probable extent of blood loss; (4) the presence or absence of large amounts of blood or air in the pleural cavity; (5) the presence or absence of cardiac tamponade; (6) the position of the mediastinum; (7) presence or absence of paradoxical respiration, or of a painful chest wall wound hindering adequate respiratory movement; and (8) presence or absence of blood, mucus, *etc.*, in the tracheobronchial tree.

As the rapid appraisal is made, indicated resuscitative measures are promptly instituted. The wound dressing is made adequate. The litter is left level, or the foot is elevated. Occasionally the dyspneic patient whose blood pressure is above 80 or 90 and who is not comatose will be more comfortable if the head and chest are elevated. With a blood pressure below 80 or a comatose patient the litter is best left level or placed in shock position. Blood replacement, autotransfusion, aspiration of hemothoraces and pneumothoraces, tracheal aspiration, intercostal nerve block, and oxygen therapy are rapidly accomplished when indicated. These measures will be discussed separately.

*Blood replacement therapy* is immediately started. Low titer Group-O blood\* is used if shock is extreme, otherwise plasma is used until the patient can be grouped and cross-matched. Lalich<sup>3</sup> has suggested a simple classification of battle wound shock to be used in estimating the amount of blood necessary and the speed with which it should be administered. It is most important in severe shock to administer blood rapidly until the pressure approximates normal, then slowly till the proper amount has been given in



preparation for surgery. Beecher and Burnett<sup>4</sup> have demonstrated the importance of the timing in replacement therapy. In their series of 37 carefully studied cases in severe shock (the worst of 2,800 battle casualties) the average time for preparation for surgery was two hours and 21 minutes. They feel that when the patient cannot have surgery at the optimum time only sufficient blood should be given to raise the systolic blood pressure to about 80 mm. Hg. and to maintain it there provided the patient is warm and of good color. More blood is then given immediately preceding and during surgery. The use of whole blood, rather than plasma, in replacement therapy is most important in chest wounds where oxygen want is often present from factors other than hemorrhage. It has been thought that the individual with a chest wound is more prone to develop pulmonary edema, from the infusion of blood or blood substitutes. Caution must be exercised to avoid giving blood rapidly after the systolic blood pressure exceeds 70 or 80 mm. Hg. As a rule, a little less blood is given when wounds involve the chest. However, the experience of most doctors in forward hospitals seems to indicate that an adequate amount of whole blood may be given, if plasma has not been given in excess, and if the tracheobronchial tree is kept relatively free of blood and mucus.

*Autotransfusion of blood* aspirated from the chest has been most useful in the resuscitation of those with chest wounds in which much hemorrhage into the pleura has occurred. As much as 2,100 cc. of blood has been aspirated from one or both pleural cavities and rapidly autotransfused. Most have avoided autotransfusion if more than 24 to 36 hours have elapsed after wounding. The blood is always filtered, and may or may not be citrated. Sanger<sup>5</sup> uses a transfusion vacuum bottle containing citrate, to aspirate acute hemothoraces, and blood so obtained may be immediately administered, using the customary recipients tubing set which has a stainless steel mesh filter incorporated. He has stressed that the blood should not be given, however, if there is any question of contamination by stomach or bowel content as there may be in a thoraco-abdominal wound. In case of doubt, the blood is held until operation proves or disproves the point in question. With low titer Group-O blood available for emergencies, this precaution is certainly indicated.

*Aspiration of hemothorax and pneumothorax* should be carried out as soon as possible in the patients with dyspnea or severe shock. The rapid restoration of the normal position of the mediastinum, and reexpansion of the lung accomplished by evacuating the pleura of blood and air are most desirable and parallel or exceed the importance of blood replacement. Intercostal nerve block may be accomplished at the same time local anesthesia is used in preparation for aspiration. Blood or air is withdrawn until the patient begins to complain of a sensation of tightness or pain in the chest. In the first 24 hours after wounding from 1,000 to 2,000 cc. of blood (or of air) may be withdrawn at one time without distressing the patient. There

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\* Group-O blood with anti-A and anti-B agglutinogens in titer less than 1-64.

has been no evidence, in our experience with hundreds of cases, that early aspiration prolongs or brings about a recurrence of hemorrhage. Air replacement is not practiced and is condemned for the following reasons: (a) It is not necessary to arrest or prevent hemorrhage; (b) it is desirable to evacuate the pleura of both blood and air to restore pulmonary function; and (c) if infection develops, collapse of the upper lobe incidental to the pneumothorax leads to total empyema rather than basal. In short, reëxpansion of the lung is the effect desired.

In those cases in which intrathoracic *hemorrhage* is continuing, the patient may require immediate aspiration to relieve respiratory embarrassment from the large hemothorax, and it may be necessary to repeat the aspiration within one to three hours. (See discussion of continuing hemorrhage below.)

The technic of thoracentesis varies in different hands. Local anesthesia should be used. If the patient has had intercostal nerve block, local infiltration of the skin at the site of puncture is all that is needed. A 17-gage needle should be used. It is connected with a vacuum bottle or with a syringe fitted with a three-way valve, so that air is not allowed to enter the chest during aspiration. In the absence of these, a short piece of rubber tubing with appropriate adaptors may be substituted, having an assistant clamp the tubing while the syringe is removed and emptied. The blood should always be aseptically collected so that it may be used for autotransfusion.

If a bronchial fistula is present, means must be provided for continuous evacuation of the air which escapes into the pleural cavity. This is best accomplished by inserting a No. 14 F. soft rubber catheter in the second interspace in the midclavicular line and connecting it with a water seal bottle.

*Tracheobronchial Aspiration.*—Tracheobronchial obstruction from blood and mucus is always encountered in varying degrees in patients with intrathoracic wounds. In some patients, tracheobronchial aspiration must be done as an emergency procedure before anything else is undertaken. In most cases, coughing will be sufficiently effective to clear the obstruction after intercostal nerve block has been performed. Encouraging the patient to cough and assisting him by supporting the injured side of his chest are helpful. In more seriously wounded patients and in patients in coma other measures are necessary. Catheter aspiration of the trachea, without topical anesthesia, as described by Haight,<sup>6</sup> may remove enough of the obstructing material to relieve the patient. Many anesthetists, surgeons, and shock officers have mastered the simple technic of this procedure. In some installations, nurses and enlisted men have been trained to carry it out in emergencies. The patient's chin should be down and the tongue pulled out. A urethral catheter with an additional hole at the proximal end is inserted through the nose into the pharynx; as the patient inspires, it is gently pushed through the open glottis. Much mucus and blood may be aspirated through the catheter, and perhaps more is evacuated by the coughing stimulated by the procedure.

The procedure is usually completed in 30 seconds to two minutes. How-

ever, in exceptional instances, it has been necessary to leave the catheter in place for a number of hours to maintain an adequate air-way.

In some instances, bronchoscopic aspiration must be used to more completely clear the tracheobronchial tree. With continuing hemorrhage into the tracheobronchial tree it may be mandatory. Shefts<sup>7</sup> found it necessary in one instance to pack a main stem bronchus to control hemorrhage which developed while a patient was being anesthetized. A thoracotomy was performed, the bleeding point controlled, and the pack then removed. In this instance, bronchoscopy was clearly an emergency life-saving measure. It is sometimes desirable to administer oxygen through the bronchoscope while doing the bronchoscopy.

*Intercostal Nerve Block.*—The relief of pain by intercostal nerve block with novocaine is of major importance in the early management of painful chest wounds. Where pain is seriously hindering respiratory movements, or preventing effective expulsion of blood and mucus in the tracheobronchial tree by cough, it should be performed immediately. Numerous reports and papers<sup>8, 9, 10</sup> from the Mediterranean Theater of Operations, have emphasized the importance of this measure in the various phases of the management of chest wounds. The effects derived from the relief of pain, permitting effective cough and deeper respiratory movements, are often dramatic. Dyspnea, cyanosis, paradoxical respiration, and tracheobronchial obstruction from blood, mucus, *etc.*, often may be relieved, or very favorably influenced, by this simple measure. The intercostal nerves, two segments above and below the lesion, are each injected with four to six cubic centimeters of 1 per cent novocaine.

*Morphine.*—Many patients have had enough or more than enough morphine administered prior to admission to an army hospital. However, some have had none, and in these the intravenous administration of  $\frac{1}{6}$  gr. of morphine plus  $\frac{1}{100}$  gr. of atropine is desirable. When indicated, this should precede intercostal nerve block and thoracentesis.

*Oxygen Therapy.*—The administration of oxygen by nasopharyngeal catheter or B. L. B. mask or anesthetic machine is indicated almost routinely in severe wounds of the chest. It must not be used to the exclusion of other more important preoperative measures outlined above. To give oxygen to a patient with an obstructed air-way is a futile gesture. Positive pressure oxygen has been used in some cases with excessive moisture (perhaps pulmonary edema) which has not been controlled by other measures.

*Completion of Preoperative Diagnosis.*—All of the above measures must be instituted rapidly and during their execution, the preoperative diagnosis is established. Points to be determined during this period include: (1) What is the trend of the pulse and blood pressure? (2) Is serious bleeding continuing or recurring as shock is controlled? (3) Is there a wound of the diaphragm? (4) Is there a large bronchial fistula? (5) Is there a wound of the esophagus? (6) Are there indriven bone fragments? (7) Are there retained foreign bodies? (8) What is the position of retained foreign

bodies? (9) What is the extent of wounds in other parts of the body, particularly those of the abdomen, spine, and skull?

*Roentgenologic Study* is essential in the determination of many of these points, but must be delayed until movement to the Roentgenologic tent will not endanger the patient. The infusion of blood is usually continued while the study is being made. Radiographs of the chest in two planes should *always* be made. Occasionally, fluoroscopic study is also desirable.

*Decision as to Optimum Time for Surgery.*—There has been some difference of opinion as to the optimum time for surgery in most wounds of the chest. The agreement is fairly general that there is not the same necessity for haste as in abdominal wounds. However, there is a group of wounds of the chest in which prompt, early surgery must be undertaken to save life. Thoraco-abdominal wounds with continuing hemorrhage from the spleen, liver, kidney, *etc.*, fall in this group. Those few cases with large broncho-pleural fistulae, or continuing intrathoracic hemorrhage, demand early, daring surgery. In such wounds, surgery often must be done before resuscitation from shock is complete. Surgery should never be postponed longer than to complete resuscitation in any thoraco-abdominal wound.

Some surgeons feel that patients with thoracic wounds may advantageously be held a number of hours after the blood pressure and pulse are stabilized. It is granted that before surgery is done, all cases must have the anatomic position and function of the thoracic organs restored to as nearly normal as is possible by conservative means. It goes without saying, that the patient must have an effective circulating blood volume. However, it is the writer's opinion that proper preoperative preparation or "stabilization" of the patient with a chest wound is attained by execution of indicated therapy and that arbitrarily delaying surgery a number of hours is to be condemned.

*Priority of Chest Surgery in Multiple Wounds.*—Experience repeatedly has taught the wisdom of giving the chest wound first-priority in surgical management of multiple wounds. If this is not done, the patient is handicapped during the other procedures by incompetent respiratory function. Defects in the pleura, whether they be through the diaphragm or the chest wall, should be securely closed before other surgery is undertaken. (Excepting those in which transdiaphragmatic surgery is done.) The pleura should be evacuated of blood and air as completely as practical. The tracheobronchial tree should be free of blood and mucus. Failure to follow these principles has resulted in catastrophe (Case 2). Hemorrhage elsewhere constitutes one of the few exceptions. This subject will be discussed further under thoraco-abdominal wounds.

*Summary of Preoperative Care.*—The most important part of the management of a chest wound is the preoperative care. Prompt and proper aspiration of hemopneumothoraces, blood replacement therapy, tracheobronchial aspiration, intercostal nerve block, oxygen therapy, and proper administration of morphine and atropine save many lives, help avoid unnecessary surgery, and

render safer whatever surgery is done. All of these measures, when indicated, should be completed prior to surgery.

#### OPERATIVE MANAGEMENT OF WOUNDS OF THE CHEST

*Replacement Therapy During Operation.*—Proper provision must be made for the intravenous administration of blood during all thoracotomies. Frequently a canula has been placed in an ankle vein during the preoperative period. If not, it should be placed before the operation is started. Through it blood may be given rapidly and the canula is not likely to become displaced. In the most serious cases the transfusion of blood is continuous throughout the preoperative, operative and immediate postoperative periods.

*Anesthesia.*—Endotracheal oxygen-ether is the anesthesia of choice for operations upon penetrating and perforating wounds of the chest. It should be administered through a machine providing CO<sub>2</sub> absorption and permitting the use of positive pressure when needed. All such wounds will suck at the time of débridement, if the débridement is complete. Positive pressure is desirable to aid in maintaining or reestablishing complete expansion of the lung. With an endotracheal tube in place, the tracheobronchial tree may be kept relatively free of blood and mucus during the operation.

*Position on the Operating Table.*—The position of the wound itself, particularly where only chest wall débridement is to be done, must influence the choice of position. Patients verging on shock, or in shock, should be kept in a head down position. This same position is desirable, whenever lung tissue has been damaged or is to be cut across, on the assumption that the likelihood of air embolism is diminished. When a posterolateral thoracotomy is to be done, the patient is placed on the sound side, with a blanket roll under the lower chest and loin, the under thigh and leg flexed and the top thigh and leg extended with the foot tied to the end of the table. Blankets or sand bags may be used to support the pelvis and the anterior chest. A broad adhesive strap from one side of the table over the upper hip to the other side of the table may be helpful.

*Choice of Operative Procedure.*—The extent of the operative procedure indicated is usually determined before the operation is started. Findings at operation may modify or change the plan. Three general types of operative procedures may be defined: (1) *Wound débridement limited to the chest wall.* In which surgery is limited to wound débridement, without inspection of or surgical procedure on the thoracic viscera. It includes aspiration of blood from the pleural cavity by insertion of a catheter through the defect in the pleura, irrigation, instillation of penicillin and occlusion of the pleural opening by suture of muscle and fascial planes. (2) *Thoracotomy through the wound.* In which débridement of the chest wall wound is done and inspection of, or surgical procedure upon, the thoracic viscera is accomplished through the wound or an extension thereof. (3) *Thoracotomy separate from the wound.* In which the thoracotomy incision is made at a site of election separate from the wound. The indications for and the technic of these different

procedures will be dealt with in the discussion of the various types of wounds.

*Simple perforating and penetrating wounds of the chest* comprise the vast majority of thoracic wounds. Excluding the thoraco-abdominal wounds, in the 1,210 cases with chest wounds reported by Sanger,<sup>5</sup> thoracotomy through the wound and separate from the wound were done in only 10 per cent. In other words, with proper pre- and postoperative care, 90 per cent of chest wounds require only *wound débridement limited to the chest wall*. This should consist of thorough excision of the wound tract down to the pleural opening. Loose rib fragments may be removed and contaminated bone ends freshened. Care is exercised to avoid enlarging the opening in the pleura. Some air nearly always enters the pleural cavity. An attempt is made to minimize this by maintaining positive pressure while the pleura is open. A catheter, inserted in the small pleural opening and connected with a suction machine, is used to evacuate any blood or air from the pleura. After the chest wall wound excision is completed, muscle and fascia layers are approximated over the pleural opening with interrupted silk or cotton sutures. The catheter is withdrawn as the stitch completing closure is tied. No attempt is made to suture the pleura itself. The skin usually is not sutured. It is well to aspirate by needle any residual pleural air at the close of operation.

Betts<sup>11</sup> has recently practiced irrigating the pleura in these simple perforating and penetrating wounds of the chest. Three hundred to 500 cc. of physiologic salt solution are injected through the catheter and then withdrawn by suction. This is repeated until the fluid returns clear, then 25,000 units of penicillin in 25 cc. of physiologic salt solution are injected through the catheter. His results would indicate that fewer postoperative aspirations are required when this has been done. Follow-up data on these cases is not sufficient to warrant final evaluation of this procedure. However, the more thorough evacuation of blood from the pleura should reduce the incidence of late clotted hemothoraces requiring decortication.

*Sucking wounds or large chest wall defects* should have very thorough débridement. Thorough washing of the pleura with physiologic salt solution and the installation of penicillin are of more importance than in simple penetrating or perforating wounds. Insertion of an intercostal catheter for water-seal drainage may be desirable if oozing or exudation is likely to continue from the lung or other intrathoracic structures. This catheter is usually best placed in the seventh interspace in the posterior axillary line, and the Malecot type catheter is preferred. In most instances, however, these wounds may be closed without drainage after irrigation of the pleura.

In these large chest wall defects it may be necessary to undermine muscle bundles bordering the wound or to swing in a pedicled muscle graft to close the defect. The use of interrupted sutures of fine cotton or silk has been found preferable to catgut in the closure of these wounds. Every effort is made to completely expand the lung at the time of closure of the wound. With positive pressure the lung is inflated out *to the chest wall* and a small catheter providing suction is left in the wound until the final occluding stitch is tied.

If a posterolateral intercostal catheter has been placed it may be left clamped off for three or four hours following surgery if one can be certain that expansion of the lung is being maintained. Some prefer to insert, in addition, a small catheter in the second interspace anteriorly and immediately connect this with a water-seal bottle. The local penicillin is not drained off until the posterolateral catheter is connected with the water-seal and unclamped three or four hours later. The anterior catheter should be removed in 12 to 24 hours unless a bronchial fistula is persisting. The posterolateral catheter should be removed in 48 hours.

Aspiration of the tracheobronchial tree by a long catheter passed through the endotracheal tube is accomplished as indicated during operation, always prior to changing the position of the patient, or expanding the lung under positive pressure, and at the close of the operation. Some feel it is important to bronchoscope every patient with a thoracic wound at the close of the operation. Aspiration of the main stem and lobe bronchi is more completely accomplished through the bronchoscope and the patient will be less likely to develop pulmonary complications.

*Indriven Rib Fragments.*—If rib fragments of any size have been driven inward, they should be removed or elevated at the time surgery of the chest wall is done. Pain and increased pulse rate often persist until this is done. Failure to elevate or remove large fragments protruding into the periphery of the lung has resulted in lung abscess. In some instances, small fragments or spicules of rib will be carried into the lung along the tract of the missile. These have been classed with other small intrapulmonary foreign bodies and have not been removed unless the chest has been opened for some other indication.

*Wounds of the lung* rarely constitute an indication for thoracotomy. A few cases have been encountered in which one or more lobes of the lung have been partially transected. These required closure with interrupted silk or cotton sutures. Lobectomy is rarely necessary. Partial lobectomy has been done in a few cases, and has usually consisted of nothing more than excision of a devitalized and partially separated tag of lung. The reparative power of the lung seems very great and excision of any lung tissue is rarely justifiable. Some difference of opinion exists as to what should be done with small wounds of the lung if the chest is opened for some other indication. Some surgeons suture the visceral pleura over every wound of the lung which is accessible, others ignore these wounds unless air or blood is escaping. A suture of the visceral pleura seems more desirable, unless it involves enlarging the incision or unduly prolonging the operation.

If a bronchopleural fistula exists it must either be closed by suture or an intercostal catheter inserted for water-seal aspiration of the escaping air. The smallest ones will usually close spontaneously under water-seal drainage within 24 hours. However, even these are best closed by suture, if this can be accomplished through the existing wound or incision.

*Large Pleural Foreign Bodies.*—Large foreign bodies which lodge in the

pleura usually produce a wound of the chest wall of such size that slight enlargement of this wound will permit removal of the foreign body. If the foreign body is of good size (2 cm., or more, in diameter) it should be removed even though this necessitates a thoracotomy.

*Intrapulmonary foreign bodies* are rarely removed in forward hospitals, except in those cases where thoracotomy is done for some other indication. When the chest is open, accessible foreign bodies should always be removed. Very large foreign bodies which have produced extensive lung damage should be removed at the time of primary surgery. Failure to do this has resulted in rapidly developing empyema and fatalities.

*Esophageal Wounds.*—A wound of the esophagus is an indication for thoracotomy. Many times it is difficult to make the diagnosis. Whenever it seems likely that such a wound exists, exploratory thoracotomy should be done; unless there are definite contraindications. In some of these wounds, or suspected wounds, the foreign body lodges in the mediastinum. In others it traverses the mediastinum and a bilateral chest wound complicates the problem. Judicious intervention, wise selection of approach and meticulous attention to all details of chest management will eliminate some fatalities.

*Continuing intrathoracic hemorrhage* is one of the rarer conditions encountered in forward hospitals. The term as used here applies to those cases in which bleeding imperils life. Diagnosis of continuing hemorrhage may be based upon the following criteria: (1) General evidences of exsanguination with only partial or no response to blood transfusion; (2) rapid reaccumulation of blood within the pleural cavity after aspiration; (3) massive clotted hemothorax with a wound suggesting the possibility of laceration of a large blood vessel; and (4) continuing escape of fresh blood from the wound. The diagnosis must be promptly made and emergency surgery performed. If the blood aspirated from the pleura is autotransfused, and other resuscitative measures promptly executed, early surgery will save the lives of most of these cases who reach the hospital alive (Case 3).

It must be constantly borne in mind that such cases occur but are extremely rare. In the vast majority of cases with intrapleural bleeding, conservative measures suffice. It is not uncommon to aspirate 700 to 1,200 cc. of blood from the chest in patients who do not have continuing hemorrhage of a degree demanding emergency surgery.

The source of the hemorrhage may be found in the chest wall and if one can be certain that bleeding is not continuing elsewhere, thoracotomy is not indicated. Continuing hemorrhage from the lung itself is extremely rare, although many wounds of the lung when exposed at operation do show slight bleeding. In many instances slight enlargement of the wound will permit the necessary exploration and intrathoracic procedures. If a large incision is necessary, it is best to make it separate from the wound and at the site of election. Large sucking wounds frequently break down in the postoperative period and if this wound forms a part of the incision, the



whole incision may dehisce, hence the advisability of a separate incision (Case 4).

A posterolateral thoracotomy through the sixth or seventh interspace or rib bed is the usual elective site for intrathoracic surgery (this does not apply to thoraco-abdominal wounds). In rare instances an anterior approach is desirable. All the procedures recommended above relative to replacement therapy, aspiration of the tracheobronchial tree, expansion of the lung at the close of operation apply, of course, to all thoracotomies. Reinjection of intercostal nerves with novocaine or crushing of the nerves immediately below and above the wound is recommended.

*Large Bronchopleural Fistula.*—A certain percentage of those with wounds of the chest have a large pneumothorax with complete collapse of the lung. The pneumothorax may or may not be under tension. Conservative management is always tried first. As described above, a small catheter is placed in the second interspace anteriorly and connected with a water-seal bottle. If expansion of the lung does not begin to take place within six to eight hours, or if during this period the patient tends to lose ground, rather than improve, a thoracotomy is indicated. Unquestionably, many die with large bronchopleural fistulae before or just after reaching a hospital. Prompt, bold surgical attention will save some of the few who reach the hospital alive. Sanger<sup>5</sup> has reported two cases of suture of the right main stem bronchus. One of these survived, the other died 72 hours after operation of concomitant wounds including a spinal cord injury.

*Wounds of the Trachea.*—A few cases with wounds of the cervical trachea have been complicated by sucking wounds extending from the apex of the pleural cavity into the neck. Tracheotomy, débridement, and proper closure of the sucking wound, have resulted successfully in most of these cases which have reached the hospital alive. Wounds of the cervical trachea not complicated by sucking chest wounds have occasionally been managed by primary suture. This, of course, is not advisable if there is much of a defect in the tracheal wall. Wounds of the intrathoracic trachea with tracheopleural fistulae have not been reported.

*Large clotted hemothoraces* have been mentioned under continuing hemorrhage. Massive clotted hemothorax occurs most frequently as a result of profuse hemorrhage. If hemorrhage has stopped, all preoperative measures should be completed, remembering that emergency surgery may be indicated at any moment with a recurrence of hemorrhage. Thoracotomy is indicated in these large clotted hemothoraces for two reasons: (1) To prevent recurrent and perhaps immediately fatal hemorrhage by securing adequate hemostasis; and (2) to evacuate the large mass of clotted blood from the pleura and secure rapid reexpansion of the lung.

*Cardiac Wounds.*—It is a relatively rare event for a patient with a wound of the heart to reach the hospital. Only one case of a wound of the heart with cardiac tamponade has come to the writer's attention.\* Lt. Col. C. B. Carter cared for this patient. The pericardium was aspirated of 500

cc. of blood and pericardiotomy was then done. A small wound of the right ventricle was successfully sutured. The patient survived the operation but died 12 to 24 hours later of other wounds, including transection of the spinal cord. There was no reaccumulation of blood in the pericardium.

Tangential wounds or abrasions of the myocardium have been observed at thoracotomy in several cases. Some of these have survived with no apparent symptoms arising from the cardiac wound. These cases may show changes in the electrocardiographic tracings but few have had clinical evidence of disturbance of the conducting system.

Wounds of the pericardium and intrapericardial foreign bodies are occasionally encountered. Most seen have been dealt with through a thoracotomy incision. The pericardium is left open sufficiently to permit drainage into the pleura. Pericardiotomy is occasionally indicated for intrapericardial foreign body.

#### OPERATIVE MANAGEMENT OF THORACO-ABDOMINAL WOUNDS

*Thoraco-abdominal Wounds.*—This includes all those cases in which the diaphragm is traversed by a missile. Left and right thoraco-abdominal wounds will be discussed separately.

*Left thoraco-abdominal wounds* comprise a very interesting and serious group. Failure to recognize such wounds has resulted in fatalities (Case 5). The possibility of the missile having traversed the diaphragm must be considered in every chest wound and abdominal wound. Exploratory thoracotomy may be indicated as a diagnostic measure. In many instances, slight enlargement of the débrided wound may permit exploration sufficient to determine the presence or absence of a wound of the diaphragm (Case 6). When a thoracotomy through a large incision is necessary, it is best to make this incision separate from the wound. However, in some the wound will be in the site of elective incision and thoracotomy through the wound is, of necessity, the selected procedure. Most surgeons familiar with thoracic surgery prefer the thoracic approach to all thoraco-abdominal wounds even though celiotomy must be done in addition. Through the open chest, the diaphragmatic wound is enlarged to permit examination and repair of accessible abdominal structures. In the great majority of instances all necessary abdominal procedures can be carried out through the thoracotomy incision. Splenectomy, repair of the stomach, mobilization of the splenic flexure are much more easily accomplished through this approach, than by celiotomy. Almost the entire small intestine, the transverse and descending colon, and the kidney are usually accessible. Wounds of the retroperitoneal portion of the splenic flexure, of the spleen, and of the posterior surface of the stomach repeatedly have been overlooked at celiotomy (Case 7). Seldom, if ever, are such wounds missed by a thoracic approach. Objection has been raised to dealing with wounds of the colon and small intestine through the chest, with the contention that infection of the pleural cavity may result. This

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\*Major Larry M. Shefts has recently seen two cases of cardiac tamponade.

objection is not valid in that whenever a wound of the diaphragm exists, contents of perforated hollow organs beneath the diaphragm will be sucked into the pleura prior to operation. Thoracotomy makes possible the thorough evacuation of feces, stomach content, or intestinal content which may be present in the pleural cavity. It is felt that in left thoraco-abdominal wounds it is wise to accomplish all surgery in the left upper quadrant of the abdomen through the thoracic approach even when it is known that a celiotomy must be done in addition.

The site of elective thoracotomy incision for thoraco-abdominal wounds is usually the ninth or tenth rib bed or interspace. Many of these thoraco-abdominal wounds involve the eighth, ninth, tenth, or eleventh ribs or interspaces. Incision in the ninth to eleventh rib bed or interspaces may be extended forward through the abdominal wall to facilitate necessary procedures within the abdomen. It is desirable to extend these incisions into the abdominal wall one or two inches if it will obviate the necessity of a separate large abdominal incision. Small muscle-splitting incisions are indicated for subdiaphragmatic drainage or exteriorization of mobilized loops of the colon.

Wounds and incisions of the diaphragm are repaired with interrupted sutures of fine cotton or silk. The diaphragmatic edges may be imbricated, or the first row of stitches inverted toward the abdomen with the second row of sutures. Diaphragmatic wounds sutured with catgut have opened up in many instances (Case 8). It is not customary to crush the phrenic nerve as a routine measure in diaphragmatic wounds. If the defect repaired was a large one, intrathoracic crushing of the nerve may be indicated.

Removal of foreign bodies from the pleura or lung, suture of the pleura over lacerations of the lung, irrigation of the pleura with physiologic salt solution, and complete reexpansion of the lung as the chest wall wound is closed should be accomplished.

Closure of thoracotomy incisions is, likewise, done with cotton or silk. Occasionally the time factor justifies the use of catgut. The time factor usually arises because of a back-log of other seriously wounded patients rather than necessity for rapid termination of the operation because of the patient's general condition.

Penicillin therapy locally and systemically is always indicated in thoraco-abdominal wounds. Some prefer the use of sulfanilamide locally in the peritoneum.

*Right Thoraco-abdominal Wounds.*—Thoracotomy is indicated in nearly every wound of the right diaphragm, regardless of the size of the missile or the size of the wound in the liver. Hemorrhage or the escape of bile may be profuse from the liver wound. A thoracotomy is done, and the wound in the diaphragm enlarged to permit institution of subdiaphragmatic drainage of the liver wound. Drainage should be accomplished by large Penrose drains with the gauze protruding from the inner end so that it may be packed loosely into the liver wound. Fatal hemorrhage has arisen from wounds of

the liver which have not been packed or sutured. The drains are invariably brought out *subdiaphragmatically* through a separate subcostal or loin incision, never across the pleural space.

Right thoracotomy incisions from the ninth to eleventh interspaces may be extended into the anterior abdominal wall to permit examination of the liver and hepatic flexure and right half of the transverse colon, the duodenum and head of the pancreas. This will frequently obviate the necessity of a separate celiotomy incision. Likewise, wounds of the posterior diaphragm may be enlarged to permit nephrectomy, suture of the kidney or establishment of drainage of the perinephric area through a stab incision in the loin.

Suture of the right diaphragm, as of the left, must be meticulously done. The use of interrupted sutures of fine silk or cotton is mandatory. Biliary pleural fistulae have occurred repeatedly when catgut was used (Case 8). Suture of the diaphragm to the chest wall (and drainage of the liver through the diaphragm and chest wall) is to be avoided. As on the left side, it is best to complete the chest surgery before making a celiotomy incision.

*Combined Thoracic and Abdominal Wounds.*—This group includes those cases in which there are both intrathoracic and intra-abdominal wounds but no involvement of the diaphragm. With rare exceptions, chest surgery should be completed before the celiotomy is done. In 15 consecutive deaths from combined thoracic and abdominal wounds, celiotomy preceded the superficial débridement of the chest wound in seven cases. In at least five of these the chest surgery should have been done first (Case 9). In only one were there definite indications for performing celiotomy first. Three cases died without surgery and the other five had chest wounds which demanded and received attention before celiotomy was done.

#### POSTOPERATIVE CARE

Bronchoscopic aspiration of the tracheobronchial tree at the termination of the operation has been mentioned. The writer is in agreement with those who favor its routine use. After the patient returns to the ward, if blood or secretions reaccumulate in the air passages, they should be aspirated by tracheal catheter suction. Rarely this is not adequate and bronchoscopic aspiration must be repeated. As soon as the patient regains consciousness, he may be able to cough up the secretions and blood as they accumulate. He should be given assistance, by supporting the chest and then by encouraging him to cough. This should be done as often as indicated and also routinely at intervals of two or three hours. Deep breathing exercises should be given at the same intervals. Tracheal catheter suction is often necessary at intervals for a number of days postoperatively. Likewise, bronchoscopy is indicated any time tracheal catheter suction does not accomplish the desired results. Arm exercises should be started after the first 24 hours.

*Pleural Drainage and Aspiration.*—Immediate postoperative needle aspiration of air from the chest, in addition to the other measures used to secure complete expansion of the lung, is important. If intercostal catheters have

been placed, they must immediately be connected with a water-seal bottle upon the patient's return to the ward. The posterolateral catheter may be kept clamped for three or four hours to allow the local penicillin time for bacteriostatic action. If pneumothorax or hemothorax recurs the catheter should be immediately unclamped. Proper attention to the water-seal bottles is most important. Errors have resulted when untrained personnel have been entrusted with their care. The water-seal bottle must be kept at least 18 inches below the most dependent part of the pleura. Whenever the bottle is emptied the tube must be clamped off. Aspiration is performed if there is any evidence of blood or air within the pleura, regardless of whether or not an intercostal catheter has been placed. Aspiration should be done daily without air replacement until the amount of blood obtained is less than 100 cc. and then every other day until the pleura is dry.

It has been found<sup>12</sup> that in thoracotomies, if the pleura is thoroughly washed with physiologic salt solution, wounds of the lung sutured, and the lung completely reexpanded, the chest may be closed without drainage. In these cases postoperative aspiration of the chest has been required far less frequently than when intercostal drainage has been employed.

*Intercostal nerve block* is indicated for the relief of pain in the postoperative period. It is seldom necessary when it has been done at the time of operation or when the intercostal nerves have been crushed at operation.

*Medication.*—Morphine should be used in small doses, if at all, in the postoperative period. Atropine sulfate may be useful in combating excessive secretion in the tracheobronchial tree. It will not remove blood and mucus, nor eliminate the necessity of tracheal aspiration.

*Oxygen Therapy.*—In severe wounds of the chest, it is well to continue oxygen therapy postoperatively. This is continued until all dyspnea has disappeared. The patient is then gradually weaned from oxygen.

*Penicillin Therapy.*—The use of penicillin is recommended in the care of all intrathoracic wounds. A dosage schedule suggested by Major Champ Lyons has been followed. Twenty-five thousand units in 25 to 50 cc. of physiologic salt solution are instilled into the pleura just prior to closure. Twenty-five thousand units are given intramuscularly every three hours for a minimum of five to seven days and until, in the judgment of the surgeon, the danger of infection is past. This usually means the lung is completely expanded, all consolidation resolved, and the pleura free of fluid and air.

*Postoperative Activity.*—Patients, even with thoracotomies, are encouraged to get out of bed as soon as water-seal catheters have been removed or as soon as they feel like it, providing their general condition or other wounds do not contraindicate. When feasible, it is desirable that patients having thoracotomies remain in the institution where the surgery was performed for 10 to 14 days following surgery. Occasionally wounds which require surgery in base hospitals warrant more rapid evacuation of the patient. The tactical situation has, at times, made it necessary to evacuate these patients earlier.

*Complications.*—Postoperative complications in chest wounds are relatively

rare. Early empyema occurs in only a small percentage of cases. These are usually managed first by closed intercostal drainage and a little later by rib resection and open drainage. It is unwise to attempt to evacuate these patients while still attempting to maintain closed drainage. Clotted hemothorax occasionally occurs postoperatively. Unless the hemothorax is of such size as to render the patient nontransportable, he is evacuated to the Base without further surgery.

Pulmonary atelectasis, or the massive collapse of the lung of World War I, rarely occurs if careful attention is paid to all the details which have been mentioned in the foregoing discussion. When it does occur, intercostal nerve block, tracheal catheter suction, or bronchoscopic aspiration are usually effective.

Subdiaphragmatic abscess has occurred early in a certain percentage of thoraco-abdominal wounds. If drainage has been properly provided at operation, it rarely occurs. Occasionally, however, a subdiaphragmatic abscess must be drained at a forward hospital.

Acute dilatation of the stomach occurs with surprising frequency in thoracic wounds, especially when a cord injury is associated. Its recognition should be prompt, in both pre- and postoperative periods, as death may result if the stomach is not promptly deflated.

Abdominal complications incidental to the abdominal part of thoraco-abdominal operations are encountered. If the chest wound has been properly and thoroughly managed, abdominal complications are little more serious than when no thoracic wound exists.

Anemia occurs in the postoperative period even when blood replacement therapy has been adequate for the preoperative and operative periods. Blood transfusions should be given early in the postoperative period and as indicated to maintain an hematocrit reading of at least 35.

#### ILLUSTRATIVE CASE REPORTS

**Case 1.**—An American soldier suffered a penetrating chest wound from a shell fragment. The wound of entrance was in the neck and was a sucking wound. He was given 500 cc. of plasma in a collecting station. He was held in a field hospital ten hours during which time he was given 750 cc. of plasma, and his blood pressure rose from 0/0 to 92/64. On admission to an evacuation hospital he was comatose, his blood pressure was 50/20, his right leg was flaccid, some air could be heard escaping from the neck, and râles were heard over the right chest. He was given 750 cc. more plasma, and 500 cc. of blood, but lived only two hours after reaching the evacuation hospital. Autopsy revealed 1,500 cc. of blood in the left chest, a comminuted fracture of the body of the seventh cervical vertebra, but no gross injury to the spinal cord.

**COMMENT:** This casualty was probably sent back to the evacuation hospital from the field hospital because of evidence of a spinal cord lesion. The notes would indicate that aspiration of the chest was not performed in either the field or evacuation hospital. Surgery of the chest wound should have been performed in the field hospital regardless of evidence of a spinal cord lesion.

**Case 2.**—An American soldier was received at a hospital a number of hours after incurring a left thoraco-abdominal wound and a compound fracture of the left humerus

from a shell fragment. Prior to admission, he had received 500 cc. of plasma and a sucking wound of the chest had been closed by suture (no débridement). On admission, the blood pressure was 110/70, and the pulse 120. Fluoroscopic examination showed increased density in the left chest and the mediastinum pushed to the right. A large foreign body lay in the region of the stomach. There was board-like rigidity of the abdomen. A wound of the left chest in the anterior axillary line had been sutured, and there was no evidence of sucking. He was given 500 cc. of plasma, and a transfusion of 500 cc. of citrated blood was started with the anesthetic.

*Operation.*—The abdomen was opened through a long left rectus incision. When the peritoneum was opened there was a gush of blood and air and the patient immediately had respiratory difficulty. A four-centimeter laceration in the dome of the diaphragm was closed with three mattress sutures of silk. Following this the patient's condition showed marked improvement. A laceration of the stomach near the greater curvature was closed. No other ruptured viscus was found. There was a small laceration of the spleen but no bleeding therefrom. A foreign body, 1 x 1 x 3 cm., was found loosely imbedded on the abdominal side of the posterior leaf of the diaphragm. It was removed. Sulfonilamide powder was dusted into the peritoneum. Shortly after the closure of the abdomen the patient developed a sucking wound of the chest at the site of previous suture. A catheter was inserted for closed drainage and the wound was packed tightly with vaselined gauze. In spite of this the patient became deeply cyanotic and died.

*Case 3.*—An American soldier was admitted to a field hospital two hours and 15 minutes after wounding. There was a sucking penetrating wound of the right chest, with wound of entrance in the first interspace just to the right of the sternum. The systolic blood pressure was approximately 60 mm. Hg., and dyspnea was pronounced. The heart and mediastinum were shifted to the left. There was hyperresonance over the right chest anteriorly and dullness in the right axilla and posteriorly. Oxygen therapy by face mask was instituted promptly and a needle with a flutter valve attachment was inserted in the right interspace anteriorly. Nine hundred cubic centimeters of blood was aspirated from the right pleural cavity and used immediately as an autotransfusion. With the aspiration of air and blood from the chest, the mediastinal shift was partially corrected and the blood pressure approximated normal. In another hour, however, the heart had shifted more to the left and dyspnea was more pronounced. Nine hundred cubic centimeters more of bright red blood was aspirated from the right pleura, and as this was started as an autotransfusion the patient was put on the operating table. The operation was started two hours and 45 minutes after admission to the hospital.

*Operation.*—A curved incision was made with the end parallel to the clavicle and sternum. A pectoral flap was turned back and the second costal cartilage and a portion of the second rib removed. The first intercostal artery and a large perforating branch of the internal mammary artery were found lacerated and bleeding. They were ligated and a laceration of the right upper lobe of the lung was sutured. The incision did not permit examination and repair of the wound in the posterior surface of the lung, nor posterior chest wall. Bleeding was completely controlled by the above procedures, so the chest was closed. In addition to the autotransfusion the patient was given 500 cc. of plasma during the operation and 500 cc. of whole blood immediately after operation. The intercostal catheter placed at operation bubbled air through the water-seal for 36 hours. The patient was in good condition but having some fever when last heard from at an evacuation hospital.

*Case 4.*—A German P. O. W. suffered a severe penetrating left thoraco-abdominal wound. He was admitted to an evacuation hospital about 20 hours after wounding, and in poor condition. Preoperatively he was given 1,500 cc. of blood, and 1,000 cc. more was given during the operation which started approximately 29 hours after wounding. There was a large defect in the left anterior chest wall involving the seventh

and eighth costal cartilages and ribs and the ninth rib. The skin defect was 5 x 6 cm. in diameter. Rib fragments were indriven, and muscle about the wound was necrotic and foul smelling.

*Operation.*—A thoracotomy through the wound was performed, making the incision over the ninth rib, and excising rib posterior to the defect. A defect, 3 x 10 cm. in size, was found in the diaphragm. The diaphragm was then incised posterior to the defect. The spleen had been cut almost in two in the middle. There was a large metallic fragment just lateral to it. Many metallic fragments were removed from along the wound tract. Splenectomy was done. The splenic flexure was mobilized and examined. It was contused but not lacerated. Approximately 1,000 cc. of blood was aspirated from the abdomen and chest during the operation. Clothing, blood clots, newspaper, and metallic foreign bodies were found in the pleura. The incision in the diaphragm was closed with one continuous chromic catgut suture and a second row of interrupted cotton sutures. The defect in the diaphragm was repaired with two rows of interrupted cotton sutures, the second inverting the first. Enough diaphragmatic substance had been lost to render the closure difficult in spite of the fact that the left phrenic nerve had been divided by the shell fragment. The pleura was washed with physiologic salt solution and 25,000 units of penicillin in solution were instilled. The defect in the pleura and chest wall was covered by a pedicled muscle flap (parsabdominalis of the pectoralis major) which was sutured to the chest wall at the margin of the defect. Muscle layers of the incision were closed with continuous catgut sutures, and the skin was sutured with cotton. At the start of the operation the blood pressure was 70/50, it rose to 115/80 during the operation, but was 90/60 at the close. Air was aspirated from the chest by catheter suction during closure and by needle aspiration at the end.

The immediate postoperative course was satisfactory. The tactical situation required evacuation of the patient on the sixth postoperative day, prior to which time a developing empyema was drained by intercostal catheter. When seen four weeks later in a general hospital, his condition was good, but the defect in the chest wall had opened and with it most of the chest wall incision. The upper lobe of the lung was partially adherent but the lower was completely collapsed. The diaphragmatic wound healed, and the cotton sutures were removed through the open chest wall wound. A plastic closure of the chest wall was accomplished about one month later.

*Case 5.*—An adult Italian woman, wounded by a shell fragment, was tagged at a battalion aid station with the diagnosis "shell fragment wound, through-and-through, entrance left breast, exit below the scapula posterior chest." The wound was dressed, one unit of plasma was administered, and the patient sent on to a collecting station. There, a novocaine block of the third to the seventh intercostal nerves was done. From the collecting station she was transferred to a clearing station and then to a field hospital, entering there three hours and 15 minutes after tagging at the battalion aid station. On admission, the blood pressure was 80/60, rising to 100/78 after transfusion of 500 cc. of blood and to 110/80 after a second transfusion of 500 cc. of blood. Two hundred cubic centimeters of blood were aspirated from the left chest. She was held at the field hospital eight to nine hours after admission, then evacuated to an evacuation hospital. There she was given three units of plasma, 500 cc. of blood and sulfadiazine and soda. Sixteen hours after admission, under local anesthesia, the wounds of entrance and exit were débrided, 270 cc. of blood were aspirated from the chest, and the fourth to tenth intercostal nerves were blocked with novocaine. Death occurred 15 hours after surgery. At postmortem, it was found that the missile had perforated the diaphragm, stomach, and spleen, as well as the left lung. Both empyema and peritonitis were well developed.

**COMMENT:** The possibility of a thoraco-abdominal wound apparently was not considered in either the field or evacuation hospital. Slight enlargement



of either wound of exit or entrance would have revealed a wound of the diaphragm. Endotracheal anesthesia should be used in the surgery of all perforating and penetrating wounds of the chest. A casualty exhibiting the degree of shock this patient suffered and having a wound which might have involved the diaphragm should have had surgery in the field hospital.

**Case 6.**—An American soldier suffered a large penetrating wound of the left chest. The wound of entrance was in the midaxillary line at the level of the seventh rib. Sucking was controlled with some difficulty. He was admitted to the field hospital unit about five hours after wounding with a pulse of 130, and blood pressure 76/30. He had been given 750 cc. of plasma prior to admission. He was given 250 cc. of plasma and 500 cc. of blood was started. The left chest was aspirated of 400 cc. of blood and 500 cc. of air. A needle was left in the second interspace anteriorly and connected with a water-seal. Three hundred cubic centimeters of the blood aspirated from the chest were given as an autotransfusion, and 250 cc. more of plasma was administered. Five hundred cubic centimeters more of blood were then given. Operation was performed 11 hours after wounding under endotracheal ether-oxygen anesthesia.

**Operation.**—The wound of the chest wall was excised and enlarged by removing the ends of the fractured seventh rib. Two large foreign bodies (0.2 x 2 cm.) were found lying together in the left dome of the diaphragm and left lobe of the liver. Some fabric was found deep to the metallic foreign bodies. These were removed. The liver was not bleeding. It was elected not to make a separate thoracotomy incision to repair the diaphragmatic wound as the liver was barely penetrated. Free rib fragments and some blood were removed from the pleural cavity. One intercostal catheter was placed in the ninth interspace posteriorly for closed drainage. The chest was closed. Another transfusion of 500 cc. of blood was given during and after the operation.

The catheter was removed 48 hours after surgery. The chest was aspirated of a small amount of bloody fluid on two occasions. The immediate convalescence was uneventful. One month after surgery, after the patient had been admitted to a general hospital, a small localized empyema developed. This was drained by rib resection, and further convalescence was uneventful.

**Case 7.**—This soldier had a left thoraco-abdominal wound in which omentum was protruding from a sucking wound in the posterior axillary line. On the night of the day of wounding a thoracotomy was performed. The diaphragm was repaired, but subdiaphragmatic exploration was not accomplished because of the poor condition of the patient. The chest wall wound was closed, and it was planned to do a celiotomy as soon as the patient's general condition improved. The celiotomy was performed the next morning, when the patient's condition was only fair. The peritoneal cavity contained a small amount of blood but no visceral injury was found. It was thought by the surgeon that the blood had entered the abdomen through the diaphragmatic wound before it was repaired. The abdomen was closed. Thirty hours after this operation 900 cc. of blood was aspirated from the left chest. The chest wound appeared clean at this time. Sixteen hours later the patient was found to be in critical condition. There was a large swelling extending from the chest wound up the left chest wall posteriorly and into the axillary area. The temperature was 108° F., and the pulse was very rapid and thready. On removing stitches from the chest wound foul-smelling gas and fluid escaped. The patient died very shortly thereafter, about 48 hours after the celiotomy. At autopsy, the latissimus dorsi muscle above and below the wound was three times normal thickness, dark red in color and filled with gas bubbles. In addition, it was found that there had been a laceration of the splenic flexure of the colon in its retro-peritoneal portion and fecal matter was escaping through the chest wound.

**COMMENT:** All necessary abdominal surgery could have been accom-

plished through the diaphragm but the surgeon felt the patient's condition would not permit it at that time. The wound of the colon could not have been discovered at celiotomy without mobilizing the splenic flexure. Through the diaphragm it would have been quite apparent and indicated surgery could have been easily performed.

**Case 8.**—An American soldier was admitted to an evacuation hospital 2.5 hours after sustaining a perforating wound of the right chest. His blood pressure on admission was 85/60. A radiograph of the chest showed a "partial hemothorax." He was given 1,000 cc. of blood, and his blood pressure rose to 140/80.

**Operation.**—A thoracotomy was performed 9.5 hours after admission. Six hundred cubic centimeters of blood was evacuated from the pleura and a two-inch laceration of the right dome of the diaphragm was sutured with catgut. He was given 500 cc. of blood during the operation. Two days later his general condition was fair and he was given 500 cc. of blood. Four days after operation, 800 cc. of bile-stained fluid was aspirated from the right chest, and it was noted that the general condition was poor. Five days postoperatively, 300 cc. of bile-stained fluid was aspirated from the right chest, 500 cc. of blood was transfused and further surgery was undertaken. The chest wound was opened, two cigarette drains were run from the liver wound out through a subcostal incision, and the diaphragm was closed with interrupted sutures of silk. A tube was placed intercostally for water-seal drainage of the right pleura. The patient died a few hours after the operation. No postmortem examination was made.

**Case 9.**—An American soldier suffered multiple shell fragment wounds. He was given morphine and 500 cc. of plasma in an aid station, and reached an evacuation hospital 6.5 hours after wounding, with a diagnosis of "penetrating wound of the right chest, with hemopneumothorax; shell fragment wound abdominal wall, right lower quadrant; penetrating wound right shoulder, with compound fracture of right humerus; lacerated wound right hand; penetrating wound left arm." He was then given 500 cc. of plasma and 500 cc. of blood. Oxygen was administered by nasal catheter. Eight hundred cubic centimeters of blood and 300 cc. of air were aspirated from the right chest five hours and 45 minutes after admission. A celiotomy was performed seven hours after admission, 13.5 hours after wounding, and under intratracheal ether anesthesia.

**Operation.**—Two large areas of ecchymosis were found in the wall of the ileum and there was some blood in the lumen of the bowel, "possibly caused by blast." The compound fracture of the humerus, and the soft-tissue wounds were débrided. "The patient died unexpectedly and suddenly," 1.5 hours after the start of the operation. "The aspirated blood had been citrated, and used as an autotransfusion, and the pulse and blood pressure had been satisfactory throughout the operation. The autopsy revealed no new information but a considerable amount of blood remained in the right pleural cavity."

**COMMENT:** The chest wound should have been débrided first, bleeding controlled, the pleura thoroughly evacuated of blood and air, the lung completely expanded and the chest wall wound closed by suture before proceeding with the celiotomy and other surgery. The patient would then have had a more competent respiratory system during the surgery on the abdomen and other parts of the body.

#### SUMMARY AND CONCLUSIONS

1. Very few casualties with wounds of the chest who survive to be evacuated from the battle field should die if properly equipped trained surgeons are available for their care.

2. Severe wounds of the chest demand first-priority management, *i.e.*, prompt care and surgery in the most forward hospital installations.

3. A surgeon familiar with both thoracic and abdominal surgery is best qualified to treat severe wounds of the chest encountered in the most forward hospitals.

4. Anesthetists well trained in endotracheal anesthesia for thoracic surgery are essential to the proper care of war wounds of the chest. Endotracheal oxygen ether, administered through a closed apparatus capable of positive pressure, is the preferred anesthesia in all perforating and penetrating wounds of the chest.

5. Prompt, well directed resuscitative measures, plus thoracotomy, are essential to the recovery of those with thoraco-abdominal wounds, those with continuing intrathoracic hemorrhage, and those with large bronchial fistulae.

6. Proper occlusion of open chest wounds with gauze and adhesive strapping is the preferred management until the patient is in a hospital equipped and staffed to do intrathoracic surgery.

7. Early and repeated aspiration of hemothoraces, without air replacement, is essential to the proper management of chest wounds. Hemorrhage has not recurred because of this practice.

8. Early aspiration of large pneumothoraces and continuous aspiration by catheter water-seal drainage of pressure pneumothoraces must be accomplished to secure a high survival rate in such conditions.

9. Intercostal nerve block to relieve pain, promote deeper breathing, and to facilitate expulsion by cough of blood and mucus in the tracheobronchial tree, is an important adjunct to therapy.

10. Tracheal catheter suction has an important place in the pre- and post-operative management of chest wounds.

11. Bronchoscopic aspiration of blood and mucus from the trachea, main stem bronchi and lobar bronchi is a good practice at the termination of every operation upon a patient with a chest wound. It may be indicated in the preoperative, operative, and postoperative periods when less radical measures fail to clear the tracheobronchial tree.

12. Replacement therapy is most important in chest wounds. Whole blood is the preferred fluid. Autotransfusion of pleural blood should be used whenever practicable. Care must be exercised to give the blood slowly after the systolic blood pressure has reached 80 mm. Hg. and to give no more blood than is necessary to attain adequate resuscitation.

13. Most wounds of the chest need only débridement of the chest wall, preceded and followed by proper chest management, replacement therapy, and oxygen therapy.

14. There are certain indications for thoracotomy through the wound.

15. There are fewer indications for formal thoracotomy by separate incision.

16. With few exceptions, surgery of chest wounds should be done first in

the case of multiple wounds, thoraco-abdominal wounds, and combined intrathoracic and abdominal wounds.

17. Most thoraco-abdominal wounds are best handled first by the thoracic approach, performing a celiotomy only if abdominal wounds cannot be cared for by the transdiaphragmatic route.

18. Evacuation from the pleura of blood, air, and all foreign bodies, and irrigation of the pleura with physiologic salt solution is desirable in the surgery of perforating and penetrating wounds of the chest.

19. Complete expansion of the lung by inflating it out to the chest wall and evacuation of all pleural fluid and air should be attained at the end of all operations in which the pleura is opened.

20. Sulfonamide or penicillin therapy should be continued until the pleura is free of all air and fluid and until any lung consolidation has resolved.

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# COMBINED INJURIES OF THE THORAX AND ABDOMEN

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BATTLE CASUALTIES with thoraco-abdominal wounds are especially interesting to the military surgeon not only because of the complicated problems which they may present but also because the results of surgery in even the most desperately injured of them are often so gratifying. There are special features in the preoperative, operative, and postoperative management of these patients which have little counterpart in civil practice and which can best be learned from experience. In the present war a larger proportion of patients with combined injuries of the thorax and abdomen survive to reach forward hospitals than ever before. Furthermore, recent advances in surgery, chemotherapy, and anesthesia, and the availability of blood and plasma at the front have combined to increase the scope and success of operative treatment.

This communication deals with the authors' experiences in the definitive treatment of these casualties in an evacuation hospital and with their care until their condition permits evacuation to general hospitals in the rear. This phase is the most critical one of their prolonged hospitalization because the eventual morbidity and mortality are determined as much by the treatment they receive at this time as by the severity of their wounds. The results we shall present are based only upon this period of observation. It is true that subsequent operations, with additional morbidity and mortality, may be necessary in some cases, but circumstances do not permit us to know the late results in our patients at this time. We are discussing, therefore, the problems met with, and the results obtained, in what is in military surgery a separate echelon in the total management of these casualties.

## CLASSIFICATION

Eighty-three patients having injury to both the thorax and abdomen were admitted to an evacuation hospital in a six-month period. They represented 21.9 per cent of the total number of patients with thoracic injuries involving hemothorax or pneumothorax, and 24.3 per cent of those with penetrating wounds of the abdomen admitted during the same period.

In its limited sense the term "thoraco-abdominal wound" refers to one in which the causative agent has traversed the diaphragm to involve both the pleural and peritoneal cavities. This was true in 66 of our cases. There are, of course, other types of combined injury to the chest and abdomen in which the diaphragm is not injured, as in the case of separate wounds of the thorax and abdomen, blunt injury to structures in both body cavities, and penetrating wounds of one cavity with blunt injury to an organ in the other. Moreover, retroperitoneal structures, especially the kidney, may be injured by a missile traversing the chest and diaphragm without penetration of the peritoneal cavity.

For this reason we have chosen to discuss all these types of wounds under the heading "combined injuries of the thorax and abdomen." Cases of blast injury to both body cavities were not included since they present different problems and have been adequately discussed in the recent medical literature of war surgery.

We have classified the 83 cases into four principal types (Table I), defined as follows:

(1) *Thoraco-abdominal* wounds are those in which a missile enters the pleural cavity first, traverses the diaphragm, and lodges in or traverses the peritoneal cavity. This was the largest group, with 53 cases.

(2) *Abdominothoracic* wounds are those with primary involvement of the abdomen followed by perforation of the diaphragm and injury to the thoracic cavity. The 13 cases in this group were placed in a separate category because of the somewhat different problems and prognosis they presented.

(3) *Thoracoretroperitoneal* wounds are those involving the diaphragm and retroperitoneal structures (commonly the kidney) without apparent involvement of the peritoneal cavity. The six cases under this heading are grouped together since the order in which these structures were injured seemed to make little difference in the outcome.

(4) *Thoracic and abdominal* injuries include (a) separate missile wounds of both cavities, seven cases; (b) subcutaneous injury to chest and abdomen by blunt trauma, two cases; and (c) missile wounds of one body cavity associated with blunt injury to organs of the other. Two cases with penetrating chest wounds associated with contusion of the kidney in one instance and of the spleen in the other belong in the last category.

#### CLINICAL FINDINGS ON ADMISSION

Details of the wounds are also given in Table I. Shell fragments were the causative missiles in 67 cases and bullets in 14. There were two instances of blunt injury alone and two combined with shell fragment injury. Penetrating wounds were more than six times as frequent as perforating ones. The wounds were on the right side in 48 cases and on the left in 33. In two instances the thoracic injury was on one side and the abdominal wound on the other. Right-sided wounds predominated presumably because left-sided ones were more liable to involve the heart and aorta and to be fatal on the battlefield.

Rib fractures were known to be present in 41 cases, of which 18 had fractures of more than one rib. The chest wound was sucking, *i.e.*, an open pneumothorax was present in 27 instances. We have discussed this group in another communication. Suffice to say that the dangers of open pneumothorax served to elevate substantially the mortality rate for patients with this complication.

Shock of some degree was present in over half of the patients on admission. It was slight to moderate in 23 cases and severe in 23 cases. Many patients had received plasma or blood at forward installations before admis-

sion. Two-thirds of the patients had some dyspnea on admission. Hemoptysis was a symptom in 19 of the group.

Pneumothorax was evident roentgenologically in 30 cases and was marked in three cases of whom two had tension pneumothorax requiring intubation of the chest for water-seal drainage.

Intrapulmonary bleeding as a result of lung damage was commonly seen in roentgenograms and was well marked in 12 instances. A diagnosis of atelectasis was made roentgenologically twice. No proved cases of pulmonary blast injury were found, but blast may have been a factor in morbidity in some patients.

One patient had symptoms of morphine overdosage on admission, and it probably contributed to his fatal outcome. Most casualties had received 0.5 gr. of morphine tartrate after wounding, and at times the full effect of the drug was not evident until they had begun to recover from shock.

Signs and symptoms which helped to confirm the suspicion of abdominal involvement were hematuria (12 cases), abdominal distention (10 cases), evisceration (four cases), hematemesis (two cases), melena (one case), and drainage of gastric content or bile through the chest wound (two cases).

Half of our cases had associated injuries of which 37 were classified as slight to moderately severe and seven as very severe. The latter group included three fractures of the vertebral column with transection of the spinal cord; three compound fractures of the extremities associated with gangrene; and one instance of compound fractures of both lower legs and one forearm. Obviously, such injuries complicating thoracic and abdominal wounds, severe enough in themselves, contribute to shock and blood loss and affect the prognosis unfavorably.

#### DIAGNOSIS

The diagnosis of combined injury of the thorax and abdomen is not difficult if it is kept in mind that any missile penetrating the chest, especially if it enters below the nipple line, may have traversed the diaphragm and entered the abdomen. Likewise, signs and symptoms of chest injury should be looked for in wounds of the upper abdomen. Occasionally they are found in wounds of the lower abdomen as well. In two of our cases the wound of entrance was in the lateral iliac region and a fracture of the ilium was present.

History-taking can be limited to a few questions about the time of wounding, the causative missile or force, and the presence of hemoptysis, dyspnea, pleuritic and abdominal pain, hematuria, hematemesis, and referred shoulder pain. Examination of the abdomen is not particularly reliable since the muscle spasm and tenderness commonly associated with these wounds are so frequently present in wounds of the lower thorax alone.

Abdominal distention, while common in left-sided thoraco-abdominal wounds, is also a frequent concomitant of wounds of the lower left thorax associated with rib fractures. Findings such as evisceration or leakage of gastric or biliary fluid through a chest wound have, of course, obvious diagnostic significance.

Physical examination of the chest gives valuable information as to the presence and severity of hemothorax, pneumothorax, rib fractures, and mediastinal deviation, and should be done carefully.

Except in the case of perforating wounds where thoracic and abdominal injuries are known to be present by the location of the wounds of entrance and exit, the crux of the diagnosis is the roentgenologic examination. The information which the surgeon desires includes the number and extent of rib fractures and bony damage to the spine and pelvis; the degree of hemothorax, pneumothorax, atelectasis, and lung hematoma; the presence or absence of air under the diaphragm; and most important, the number and location of foreign bodies, so that he may reconstruct the course of the missile from the wound of entrance. The services of an expert roentgenologist are most helpful in this regard. Most often the foreign bodies were reported to lie in the abdomen or abdominal wall (34 cases). In 20 the missiles were within the thoracic cavity or in the chest wall, and in six there were foreign bodies in both the chest and abdomen. In a few cases patients either died before roentgenograms were made or were operated upon without films because of the obvious and desperate nature of their injuries. It was sometimes difficult to determine whether a particular foreign body was above or below the diaphragm in the roentgenogram. If this were the case in a left-sided wound it was thought best to assume that the peritoneal cavity had been entered and to plan the operation accordingly.

As a usual procedure anteroposterior and lateral films of the chest and abdomen were made in suspected cases. In a few cases of penetrating wounds where roentgenograms of only the chest or abdomen had been ordered, the missile was seen imperfectly or not at all in these films, and it was necessary to return the patient for additional examination to locate it in the other body cavity.

#### PREOPERATIVE TREATMENT

Patients thought to have combined injuries of the chest and abdomen were treated in a shock ward where oxygen therapy was instituted for those with dyspnea and cyanosis. Transfusion of blood was begun as soon as possible in those showing signs of shock and hemorrhage. Stored Type "o" whole blood was preferred to that mixed with an equal volume of Alsever's solution since multiple transfusions were often necessary. The larger volume required using the latter preparation was a hazard when given to patients with severe chest injury because they were more prone to develop pulmonary edema than were other wounded. Patients who received large amounts of blood and plasma were, therefore, observed for signs of pulmonary congestion and edema and infusions of saline were avoided.

Twenty-nine patients received 1,000 cc. of blood or less before and during surgery; 17 were given 1,500 cc. to 2,000 cc.; and six received 2,500 cc. or more. The amount of blood given depended upon the estimated loss and upon the response of the blood pressure, pulse, and hematocrit readings to



therapy. Most patients received 500 cc. to 750 cc. of plasma as well, but plasma alone was used in only nine cases.

Examination of the chest and abdomen was carried out as completely as practicable and the wounds inspected and redressed. Sucking chest wounds were occluded temporarily by a vaselined gauze dressing and tight adhesive strapping. The patient was also surveyed for associated injuries, with special regard to spinal cord damage since paraplegia may go unnoticed at first in a severely injured patient.

Hemopneumothorax large enough to produce considerable dyspnea required preoperative aspiration in seven of our cases, and in two instances intubation of the chest with water-seal drainage was instituted for tension pneumothorax.

The routine use of a Levine tube for gastric distention before surgery is recommended, particularly in left-sided injury. The tube does not interfere with the administration of the anesthetic and may be left in for resumption of gastric suction on the postoperative ward.

Penicillin therapy was begun in all cases in dosages of 20,000 units every four hours given intramuscularly. Sulfadiazine was not given by mouth to patients with suspected abdominal injury. In some instances sodium sulfadiazine was given intravenously. The administration of morphine was kept to a minimum,  $\frac{1}{8}$  gr. intravenously or  $\frac{1}{6}$  gr. hypodermically being given for pain if necessary. The urine was always examined grossly for blood and a specimen sent to the laboratory in doubtful cases.

Patients with dyspnea were more comfortable reclining on a back rest, and when out of shock and comfortable without oxygen they were sent for roentgenograms in this semisitting position.

Chest films were taken with the patient sitting when possible, but in many cases they were taken with him reclining or supine, and occasionally even through the litter. The manipulation attending the taking of roentgenograms not infrequently was followed by an increase in pulse rate and fall in blood pressure in severely wounded cases, and they were allowed to recuperate with oxygen therapy for a time before being sent to surgery.

The interval between wounding and admission varied considerably, depending on the tactical situation. The average interval between wounding and surgery was 17.6 hours. The time interval between admission and surgery averaged 11.4 hours, but also varied considerably, depending on the patient's response to shock therapy, the seriousness of his wounds, and the number of other urgent cases on the surgery schedule.

#### OPERABILITY

Thirteen of the 83 patients in our series were not operated upon. Ten were considered inoperable and in three no operation was thought to be indicated. Of the latter group, two had small penetrating right-sided thoraco-abdominal wounds with minimal hemothorax and roentgenologic evidence of small shell fragments in the liver. Both patients were evacuated on the

second day without operation. Cases with small perforating gunshot wounds of the right costophrenic sinus and right lobe of the liver not associated with rib fractures would also belong to this category. The other patient was a 17-year-old French girl who had sustained a penetrating shell fragment wound of the right lateral inferior chest six days prior to admission. There was profuse biliary and seropurulent wound drainage and roentgenograms showed a moderately large hemothorax with several shell fragments in the right lobe of the liver. The chest fluid soon became frankly purulent and frequent aspirations and instillation of penicillin were carried out. She made good progress until the time of her evacuation to a civil hospital. Subsequent surgical drainage of the empyema and removal of the foreign bodies from the liver were recommended.

Eight of the ten patients who died without surgery expired 12 hours or less from the time of admission. Two patients sustained severe blunt injury to the left side of the chest and abdomen followed by shock, dyspnea, and hematuria, and one of them had a bilateral pneumothorax, tension in type, on the left side. Another patient had a penetrating left thoraco-abdominal wound with tension pneumothorax as well as multiple shell fragment wounds and fractures of three extremities and evidence of an overdose of morphine. Two other left-sided cases and one right-sided case died of shock and hemorrhage which did not respond to multiple transfusions. One patient with separate perforating gunshot wounds of the right side of the chest and left side of the abdomen died five minutes after admission. The eighth patient was admitted 50 hours after he had sustained a penetrating wound of the right lumbar region associated with hemopneumothorax. He was in fairly good condition on admission but soon afterward suddenly began to cough up bloody fluid, and died within a few minutes, presumably from aspiration of chest fluid through a bronchopleural fistula. Another patient with a penetrating chest wound involving the subclavian artery and a perforating wound of the abdomen died of shock 20 hours after admission. It was decided to forego operation in the case of the tenth patient because of his poor prognosis and because operation could accomplish little. A bullet had entered the right iliac region, fractured the ilium and three lumbar vertebrae extensively, producing a cord transection, and had lodged in the lateral costophrenic sinus where a small hemothorax was evident. A large retroperitoneal hematoma and kidney injury were believed to be present. He died on the sixth day after admission.

Except in such cases in which operation offered nothing, however, every attempt was made to get severely wounded patients to the operating room if it was thought that shock therapy could do no more to improve their condition. The arrest of hemorrhage at operation may offer them the only chance of surviving. Three of the operative deaths in our series occurred on the table after such procedures, but the lives of several patients with an almost equally bad prognosis were saved.

The surgeon must be concerned with the total mortality rate rather than

the operative mortality and must not hesitate to attempt to decrease the former at the expense of the latter. Excluding the three cases for whom no operation was indicated, our operability rate was 70 in 80 cases, or 88 per cent.

#### OPERATION

The choice of operative procedure depends almost entirely upon which organs have been injured and to what extent. The anatomic involvement in the 70 operated cases is given in Table II. The surgical approach to these concomitant injuries of the thorax and abdomen is the most important point in technic. The decision to operate through the thorax, the abdomen, or both, should be dictated by certain indications, rather than by the surgeon's personal preference for working in either the chest or abdomen.

The operating time is an important consideration in these patients and major operative procedures on both the thorax and abdomen should be avoided if a single approach will suffice. Thus, only 12 of our 70 operated cases were subjected to both thoracotomy and celiotomy.

The five principal types of operation are listed in Table III, and the details of operations in Table IV. The indication for these will be discussed separately in the following paragraphs:

(1) *Thoracotomy with Transdiaphragmatic Operation*: The selection of this operation should have as its first requisite the presence of sufficient thoracic involvement to warrant thoracotomy, irrespective of the type and extent of abdominal involvement. The usual indications for thoracotomy are: The presence of large retained foreign bodies in the thoracic cavity; extensive compound rib fractures with indriven fragments; large sucking chest wounds; severe hemothorax thought to be due to lung laceration or to major bleeding from the parietes or mediastinum; and diaphragmatic herniation.

Thoracotomy was indicated in over half of our patients and sufficed in 30 cases, the abdominal exploration and repair being performed transdiaphragmatically. Of particular significance in this regard is the data in Table II. In the 70 operated cases the liver was involved 39 times, the stomach 15, the spleen 15, the kidney 12, the small intestine five, and the large intestine five. The three organs most frequently involved, therefore, are for the most part accessible to transdiaphragmatic approach, and, in fact, are more easily operated upon than by the transabdominal route. On the other hand, involvement of the kidney, small intestine, and colon, organs best approached by other routes, is less frequent. In one case, however, thoracotomy and removal of a shell fragment in the right lower lobe of the lung was performed through a kidney incision after suture of a lacerated kidney. In another instance transthoracic repair of a kidney was performed, and in a third case exteriorization of a perforated splenic flexure of the colon was effected by stab incision of the abdominal wall during a transdiaphragmatic operation.

Fractures of the sixth, seventh, or eighth ribs were commonly present in

# THORACO-ABDOMINAL INJURIES

TABLE I

CLASSIFICATION AND CLINICAL FINDINGS IN 83 CASES OF COMBINED INJURY OF THE THORAX AND ABDOMEN

Type of Wound	Total Cases	Penetrating and												Total	
		Penetrating Wounds		Perforating Wounds		Perforating Wounds		Right-Side Wounds		Left-Side Wounds		Bilateral Wounds			
		Shell	Bullet	Shell	Bullet	Shell	Bullet	Lived	Died	Lived	Died	Lived	Died	Lived	Died
1. Thoraco-abdominal	53	43	4	1	3	2	0	29	5	17	2	0	0	46	7
2. Abdomino-thoracic	13	8	1	1	2	1	0	4	0	3	5	0	1	7	6
3. Thoraco-retroperitoneal	6	3	0	2	1	0	0	5	1	0	0	0	0	5	1
4. Thoracic and abdominal:															
a. Separate missile wounds	7	4	0	1	1	0	1	1	2	0	3	0	1	1	6
b. Subcutaneous injury	2	0	0	0	0	0	0	0	0	0	2	0	0	0	2
c. Subcutaneous injury and missile wounds	2	1	1	0	0	0	0	1	0	1	0	0	0	2	0
Totals	83	59	6	5	7	3	1	40	8	21	12	0	2	61	22

TABLE II

INVOLVEMENT OF ABDOMINAL ORGANS IN 70 OPERATED CASES

Type of Wound	Total Cases	Right	Left	Total	
				Lived	Died
1. Diaphragm only:					
a. With diaphragmatic hernia.....	2	0	2**	1	1
b. Without diaphragmatic hernia.....	3	2	1	3	0
2. Liver only.....	27	26	1	24	3
3. Spleen only.....	7	0	7**	7	0
4. Kidney only.....	5	5	0	5	0
5. Stomach only.....	5	0	5*	3	2
6. Liver and kidney.....	5	5	0	4	1
7. Spleen and kidney.....	2	0	2	1	1
8. Stomach and liver.....	3	0	3	2	1
9. Stomach and spleen.....	2	0	2*	1	1
10. Stomach, liver and spleen.....	1	0	1	1	0
11. Stomach and small intestine.....	2	0	2	2	0
12. Stomach, colon and spleen.....	1	0	1*	0	1
13. Stomach, liver, small intestine and colon.....	1	0	1	1	0
14. Small intestine and liver.....	1	1	0	0	1
15. Small intestine, colon and liver.....	1	1	0	1	0
16. Colon and spleen.....	2	0	2	2	0
Totals.....	70	40	30	58	12

\*Each asterisk represents one instance of associated diaphragmatic hernia (total number 7).

lateral wounds, and of the ninth and tenth in posterior wounds. The incision was usually made over the fractured rib and included the wound of entrance which was excised. Resection of the fractured rib was performed in two-thirds of the cases. In the others intercostal thoracotomy was performed. Suture of the lung was necessary in eight cases. In five cases foreign bodies were removed from the lung or pleural cavity, and in seven diaphragmatic

TABLE III  
TYPES OF OPERATION IN 70 OPERATED CASES

Operation	Total	Right		Left		Total	
		Lived	Died	Lived	Died	Lived	Died
1. Thoracotomy and transdiaphragmatic operation.....	30	13	3	10	4	23	7
2. Thoracotomy and transdiaphragmatic operation with celiotomy.....	12	7	1	2	2	9	3
3. Celiotomy.....	18	6	1	10	1	16	2
4. Kidney exploration.....	3	3	0	0	0	3	0
5. Miscellaneous minor operations.....	7	6	0	1	0	7	0
Totals.....	70	35	5	23	7	58	12

TABLE IV  
DETAILS OF OPERATIVE PROCEDURES

Procedures	Total	Thoracotomy and Trans- diaphragmatic Operation	Thoracotomy and Trans- diaphragmatic Operation with Celiotomy	Celiotomy	Kidney Exploration	Miscellaneous Minor Procedures
Repair of diaphragmatic hernia.....	7	7	0	0	0	0
Repair of liver by suture....	19	5	8	6	0	0
Repair of liver by packing...	4	1	2	1	0	0
Repair of stomach.....	14	6	2	6	0	0
Splenectomy.....	12	7	2	3	0	0
Nephrectomy.....	2	0	2	0	0	0
Suture of kidney.....	6	2	0	1	3	0
Suture of small intestine....	4	0	1	3	0	0
Resection and end-to-end anastomosis of small in- testine.....	2	0	1	1	0	0
Exteriorization of the large intestine.....	5	1	1	3	0	0
Wound débridement, chest aspiration, etc., only.....	7	0	0	0	0	7

herniae were reduced. Phrenic emphysexis was done only once since function of the diaphragm in reëxpansion of the lung seemed more important than other considerations. Closure of the diaphragm was made with No. 2 chromic catgut and medium silk sutures overlapping the leaves. The thoracic wall was closed preferably with two layers of muscles. The skin was closed with interrupted sutures. Dependent closed intercostal drainage was instituted with a No. 18 F. catheter.

Thoracotomy was performed on the right 16 times, the usual abdominal injury being a penetrating wound of the liver with a retained missile. If

the perforation of the diaphragm was of some size it was enlarged and the dome of the liver exposed and sutured if necessary. Drainage of the abdominal cavity to permit the escape of bile can be done by stab incision of the abdomen made through the diaphragm. While celiotomy is necessary for many large wounds of the liver which may require packing some may be managed transdiaphragmatically by the application of a vaselined gauze pack brought out through the abdominal wall under the diaphragm. The problem of hemorrhage from the majority of missile wounds of the liver is not as great as that in fracture of the liver seen in civil practice.

In the 14 left-sided injuries in this group transthoracic repair of the stomach was performed six times and transthoracic splenectomy seven times. From the technical standpoint both removal of the spleen and repair of the stomach are more easily performed through the chest. The difficulties in exposure for splenectomy and repair of high perforations of the stomach by celiotomy are well known. Likewise, suture of the diaphragm and repair of diaphragmatic hernia are more awkward and time-consuming by the trans-abdominal approach.

There were seven deaths among these 30 patients. Three severely wounded patients died of shock after operation, and a fourth of massive pulmonary hemorrhage. Two died with empyema; one patient had a bilateral empyema, secondary to bilateral bronchopneumonia and tension pneumothorax with bronchopleural fistula on one side. The other patient developed gangrene of the left lower lobe and empyema secondary to an abdomino-thoracic shell fragment wound in which feces from the splenic flexure of the colon had contaminated the pleural cavity.

(2) *Thoracotomy and Transdiaphragmatic Operation, Combined with Celiotomy*: Both operations are, of course, necessary when indications exist for each. In this event the operation calculated to do the patient the most immediate good should be undertaken first. Usually thoracotomy, with evacuation of the hemothorax, arresting of the bleeding, or closure of a sucking wound is most compelling.

When a thoracotomy has been performed first the decision to explore the abdomen as well depends primarily upon the presence of perforation of the intestine. The latter may be obvious at transdiaphragmatic exploration, or may have been suspected from the clinical findings or from the presence of intra-abdominal foreign bodies in the roentgenograms, especially if these are lodged below the level of the first lumbar vertebra. Occasionally the surgeon may have decided that the necessary exploration and repair could be carried out through the thorax only to find at operation that the injuries were less accessible or more extensive than he had calculated. For example, he may find that an injury to the liver requiring suture or packing extends to its inferior surface. In severe intestinal injury with intra-abdominal bleeding, however, celiotomy may be required first.

Four of the 12 cases in this category were subjected to thoracotomy first, then celiotomy through a separate incision. Transthoracic splenectomy in

one instance and repair of the liver in another actually sufficed but celiotomy was performed because of the possibility of perforation of the intestine. In a third patient a large anterior laceration of the liver was found at thoracotomy, and it was closed with the aid of free omental grafts through an abdominal incision. The fourth patient exemplifies how extensive thoraco-abdominal injuries may be and be operated upon successfully. At thoracotomy, perforations of the stomach and of the left lower lobe of the lung were sutured, a laceration of the liver sutured, and a diaphragmatic hernia repaired. At celiotomy, six inches of gangrenous jejunum was resected and an end-to-end anastomosis performed; an additional perforation of the jejunum was sutured, and a perforated portion of the transverse colon was exteriorized.

A fifth patient had a preliminary celiotomy for bleeding from the liver followed by thoracotomy and suture of the diaphragm.

Seven patients in the series had wounds involving tears of the attachment of the diaphragm to the chest wall, and a single incision sufficed to permit exploration of the involved portions of both cavities and reattachment of the diaphragm. In two of these nephrectomy was necessary, and the kidney incision was carried anteriorly to the flank to permit suture and packing of a liver wound in one instance, and splenectomy in the other. In two patients a right flank incision was employed for repair of wounds of the liver and diaphragm. Combined operation through an anterior approach was done in three other cases. In two of these repair and packing of the liver and closure of the anterior pleural defect were performed through a right rectus incision. The other patient had eviscerated through perforating wounds of the upper abdomen and had a sucking defect of the diaphragm anteriorly. A transverse upper abdominal incision was used in this instance.

The last mentioned patient and one of the two in whom nephrectomy was performed died on the operating table while attempts were being made to control hemorrhage. A third patient with severe liver and kidney injury died of anuria and uremia a week postoperatively. These represented the three deaths among the 12 patients subjected to combined thoracotomy and celiotomy.

(3) *Celiotomy*: Celiotomy alone is indicated in that group of patients in whom injury of the chest has been minimal and injury of the colon, small intestine, or inferior surface of the liver is suspected. Not infrequently, local débridement of chest wounds and closure of the pleura may be needed and often postoperative aspiration of an hemothorax must be done. If there is a considerable hemothorax, closed catheter drainage of the pleural cavity for 48 hours should be performed. If contamination of the pleural cavity by gastric content or bile has occurred drainage of the chest should be continued longer and intrapleural penicillin therapy instituted daily. Perforations of the diaphragm should be closed after aspiration of the pleural cavity with a sucker inserted through the diaphragm. Suture of the diaphragm from the abdominal approach is liable to be difficult, especially on the right.

Eighteen patients were subjected to celiotomy alone or in combination

with minor chest procedures including aspiration of the pleural cavity or closed drainage. The operative procedures require no discussion here and are listed on Table IV. There were two deaths in the group. One patient died of bilateral bronchopneumonia and atelectasis following a right-sided wound of the liver and duodenum; the other had separate penetrating wounds of the thorax and stomach with a compound fracture of the femur and gangrene of the lower leg. He died with an empyema the day following amputation.

(4) *Exploration of the Kidney:* Three patients in the group of thoraco-retroperitoneal injuries were operated upon by an incision permitting exposure and suture of the kidney and suture of the diaphragm. The latter was done in two cases. In each instance, thoracic injury was minimal, and considerable hematuria was the indication for the operation. There were no deaths in this group.

(5) *Miscellaneous Minor Operations:* Into this category fall that group of minimal concomitant thoracic and abdominal injuries from small missiles which in passage through the thorax cause damage insufficient to warrant more than aspiration of a hemothorax or hemopneumothorax and which, likewise, have produced damage in the abdominal cavity which needs no operative treatment. The classical cases are those involving the right side of the body in which one finds a small chest wound with a small hemothorax and roentgenologic evidence of a small shell fragment in the liver. Accurate reconstruction of the course of the missile from its entrance to its lodgement is important if futile major operations are to be avoided.

There were seven patients treated by relatively minor procedures. One had a left-sided wound with suspected involvement of the spleen and sub-diaphragmatic bleeding. This conservative treatment was undertaken with some misgiving because of the danger on the left side of gastric perforation. Pain in the shoulder was present, a sign which usually indicates diaphragmatic irritation. In general, a conservative management of left-sided lesions is not recommended. Six patients had right-sided wounds, four of which involved the liver and one the kidney. In the other case, the pleural and peritoneal cavities had been opened by the missile without any visceral damage. Local débridement of the wounds with or without chest aspiration was carried out. In three cases small tears in the pleura were closed and in one a peritoneal laceration was sutured. There were no deaths in the group and all patients were evacuated in good condition.

#### ASSOCIATED INJURIES

In over one-half of our patients additional operations for associated injuries were required, among which compound fractures of the extremities were most common. As a rule débridement and plaster encasement was done at the end of the more urgent operation. In severely injured patients, however, operation upon an extremity was sometimes delayed from 24 to 72 hours. The possibility of the development of serious infection in an untreated



contaminated wound is not inconsiderable but is a less serious risk than subjecting a patient already in shock to further blood loss and trauma. The systemic use of penicillin and sulfadiazine, with adequate immobilization of the extremity, lessens the chance of serious infection.

When débridement of compound fractures of the humerus was done along with a thoracic operation, the temporary use of a full-arm plaster encasement is sufficient for immobilization in the hospital. A Velpeau plaster dressing was applied for transportation. In two patients leg amputations were performed and one an arm amputation.

#### ANESTHESIA

Endotracheal ether anesthesia was employed in 50 of the 70 operated cases, and 13 others were given an ether-oxygen mixture from the anesthesia machine. The former was preferred both for thoracotomy and for celiotomy because an air-way was assured, respiration could be controlled; upper abdominal relaxation was improved; and aspiration of tracheobronchial secretions during and after surgery was facilitated.

Sodium pentothal supplemented by nitrous oxide and oxygen was used in three cases where operation was limited to débridement and exploration of the wound. Local procaine infiltration sufficed in three other procedures of this type, and was also employed in one patient with severe shock and hemorrhage associated with evisceration through the chest wound. Generally speaking, the application of agents and methods other than the endotracheal administration of ether was limited to exploration of kidney wounds and right-sided injuries not requiring open thoracotomy.

Postoperatively the anesthetist aspirated the trachea with a catheter, and occasionally bronchoscopic aspiration was carried out. If the patient was in poor condition at the end of the operation, he was kept on the table for an hour, or more, while the administration of oxygen and blood was continued before being sent to the postoperative "chest and abdomen" ward.

#### POSTOPERATIVE MANAGEMENT

Oxygen therapy was usually continued on the ward for several hours after operation. Blood and plasma were given as necessary for continuing or increasing shock and signs of pulmonary edema were watched for. Apart from the treatment of postsurgical shock, over one-third of these patients required additional transfusions during the postoperative period.

Gastric suction was instituted in left-sided cases and in any patient in whom gastric distention had been present preoperatively. Right-sided wounds were less troublesome in this regard. Three thousand cubic centimeters of dextrose in water or saline and 250 cc. of plasma were given daily to patients with gastric suction.

The usual precautions for the prevention of atelectasis were observed. Patients who had not had a celiotomy were allowed to recline on a back-rest and to sit up as soon as practicable. Deep breathing exercises were started at the outset to encourage reëxpansion of the lung.

The administration of penicillin intramuscularly in doses of 20,000 units every four hours was continued. Six grams of sulfadiazine a day was given orally to patients without gastric suction, provided there was no serious kidney injury. Intravenous sodium sulfadiazine was not employed routinely, but only when such complications as postoperative atelectasis or bronchopneumonia were evident.

In patients with closed drainage of the chest, the patency of the catheter was checked at intervals by irrigation with a little saline. Forty thousand units of penicillin in 20 cc. of saline was injected into the tube before its removal 40 to 48 hours after operation. When there had been gross contamination of the pleural cavity with gastric or intestinal content or when there was much bile in the pleural fluid, however, the catheter was left in for three days or more.

Reaccumulation of the serosanguineous fluid after removal of the tube was common, especially after transdiaphragmatic operations. Usually one aspiration sufficed, since, ordinarily, no attempt was made to aspirate fluid if roentgenograms showed it to be small in amount. Other cases required two to four aspirations by reason of pleuritis due to biliary or other contamination of the pleural cavity, suspected empyema, or some other cause. Penicillin was injected after each aspiration and air was removed as completely as possible to encourage early reëxpansion of the lung.

In some instances it was necessary to transfer patients to the care of another hospital unit before they were ready to be evacuated. Our policy was to keep postceliotomy patients for ten days or longer, and postthoracotomy cases for at least seven days. Patients with nonserious right-sided or thoracoretroperitoneal injuries were often held for only three to five days. A number of our patients were evacuated by air since it was believed that they would stand the trip better by air transport at low altitudes than by ambulance or ship.

#### POSTOPERATIVE COMPLICATIONS

The serious complications among the patients who died following surgery have already been discussed in the section dealing with the various operative procedures and will only be summarized here.

Shock due to trauma and operation was the most common fatal complication (seven cases). Pulmonary complications were frequent and included five cases of postoperative atelectasis, four of bronchopneumonia, two of tension pneumothorax, two of pulmonary edema (both of which were fatal), three of empyema (all of whom died), two of severe hemoptysis, one of bronchopleural fistula, and one of gangrene of one lobe of the lung. Bile was evident in the pleural fluid in six instances, and there was biliary drainage from the chest wound in two patients. Many patients had some degree of hydrothorax or pneumothorax on evacuation, and it is likely that some cases of empyema and nonreëxpansion of the lung appeared after they had left our hands.

Anuria and uremia were fatal in one patient. Another developed a fecal fistula in the abdominal wound of entrance near his colostomy. Moderate peritonitis was due to contamination from perforation of the intestine in four cases, and in two others, to bile in the peritoneal cavity.

Abdominal distention persisting in spite of gastric suction was troublesome in seven patients. Some degree of wound infection was present in five cases, though it may have appeared later in other instances. Persistent paroxysmal auricular tachycardia occurred in one patient, who died. Transfusion reactions were relatively common (six cases), and were probably due to the use of stored Type "o" blood, and to the frequent use of multiple transfusions. One patient had a severe reaction with temporary renal shutdown, but recovered with alkalization therapy.

DISCUSSION.—Combined injuries of the thorax and abdomen in this series accounted for about one-fourth of all penetrating or perforating wounds of the chest and abdomen. Chest and abdominal wounds each give rise to problems in management; when both are present, difficulties may be doubled and certain problems peculiar to combined injuries are added. Furthermore, more than half of these patients had associated injuries of varying severity. That left-sided wounds are more serious than right-sided ones was evidenced not only by the smaller number of the former who lived to reach the hospital but also by their higher hospital mortality. Twelve of the 33 patients with left-sided injuries died, while eight of the 48 with injuries on the right side succumbed. Both patients with chest injury on one side and abdominal injury on the other died (Table I). On the right side the liver offers an important barrier to missiles and perforation of the intestine is less common than on the left.

The clinical classification of these types of wounds into four groups implies by nomenclature the possible involvement, surgical approach, and prognosis. In this series, *thoraco-abdominal* wounds were most common and exceeded the combined total of the others. *Abdominothoracic* wounds were distinctive because they were more serious than the former; six of the 13 patients in this category died, abdominal injury was more extensive, shock more severe. Three of these patients had evisceration. The term *thoraco-retroperitoneal* designates those wounds involving the thorax and the kidney. The classification is completed by including other concomitant injuries of the chest and abdomen due to separate missiles or to blunt force in a fourth group called *thoracic and abdominal* injuries. Separate wounds of the abdomen and chest were associated with the highest mortality.

From the diagnostic standpoint, it is most important first to keep in mind the frequency with which both cavities are involved in missile wounds of one or the other. While the diagnosis may be clinically obvious from the signs and symptoms and from the location of the wounds, roentgenologic search for all missiles and reconstruction of their course will reveal the diagnosis when the clinical findings are equivocal. Experience in the corre-

lation of the findings at operation with the roentgenologic data aids in predicting organ involvement and in planning the surgical approach.

Every attempt must be made to bring even the most seriously injured patients to surgery since the arrest of hemorrhage and the correction of respiratory physiology may offer the best treatment for their shock. Over-caution in delaying operation until shock therapy has produced satisfactory pulse and blood pressure readings may be fatal in these cases. Patients who require thoracotomy because of a large hemothorax or sucking chest wound usually improve during surgery. Patients with severe abdominal injury also frequently improve during operation, but to a lesser extent. Excluding three cases in whom no surgery was indicated, 70 of 80 patients were operated upon and ten died without operation, making the operability rate 88 per cent. Although operative attempts to save desperately injured casualties may prove futile, the operative mortality rate should be disregarded in the effort to save at least some of the patients.

The proper course of treatment of combined injuries varies from no surgery at all to the most extensive combined thoracic and abdominal operations. Conservative management has an important place in the treatment of right-sided injuries involving small penetrating or perforating wounds of the liver or kidney without serious intrathoracic damage. Occasionally nothing need be done; in others, débridement and exploration of the wound, closure of the opening in the pleura, and aspiration of the hemothorax is indicated. These procedures along with suture of the kidney usually suffice for thoracoretroperitoneal wounds as well. Thoracotomy was performed 42 times, but in only five instances was a separate celiotomy incision necessary, and in seven cases exploration and repair of the involved portions of the thorax and abdomen were carried out through the same incision. Transdiaphragmatic procedures on the liver, spleen, and stomach are technically easier than if performed at celiotomy. On the other hand, celiotomy alone should be performed if intrathoracic damage is minimal. If both thoracotomy and celiotomy are necessary, the one which will do the patient the most immediate good should be undertaken first. Unless intraabdominal bleeding is present, thoracotomy should take precedence, since the correction of pathologic physiology due to open pneumothorax or a large hemothorax greatly improves the patient's general condition and increases his ability to withstand other necessary surgery.

There were 22 deaths in this series of 83 cases, a fatality rate of 27 per cent.

Of the 70 patients operated upon, 12 died, a mortality rate of 17 per cent. Five of these deaths occurred among the 40 right-sided cases, and seven among the 30 patients with left-sided wounds.

The operative mortality rate among patients subjected to thoracotomy and transdiaphragmatic operation was 23 per cent (seven deaths in 30 cases). Two of the 18 patients who had a celiotomy only succumbed, a fatality rate of 11 per cent. None of the ten patients died for whom the

relatively minor procedures of wound exploration with or without suture of the kidney had been performed. Among the operated cases perforation of a hollow viscus was associated with a mortality rate of 32 per cent. When a solid viscus alone was involved, the mortality rate was 11 per cent. Injury to the diaphragm without damage to abdominal viscera was present in five cases. Diaphragmatic hernia was present in three of these and there was one death in the group.

#### SUMMARY AND CONCLUSIONS

Eighty-three cases of combined injuries of the thorax and abdomen treated in an evacuation hospital have been discussed. A classification of these injuries into four principal types have been presented.

The wounds were right-sided in 48 cases (eight deaths) and left-sided in 33 patients (12 deaths). Both patients died in whom the chest on one side and the abdomen on the other were involved. The operability rate was 88 per cent. Half of the patients had associated injuries.

Five principal types of operation were carried out: (1) Thoracotomy and transdiaphragmatic operation; (2) thoracotomy and transdiaphragmatic operation combined with celiotomy; (3) celiotomy alone; (4) repair of the kidney, and (5) wound exploration with suture of the pleura if necessary. The indications for each type are discussed.

Five of the 40 right-sided cases, and seven of the 30 left-sided cases operated upon died during the period of observation. The operative mortality rate was 17 per cent.

# COMPOUND, COMMINUTED SKULL FRACTURES PRODUCED BY MISSILES

REPORT BASED UPON 100 CASES

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IN THE HOPE of adding something to the picture of head wounds 100 consecutive cases of compound, comminuted fractures of the skull have been analyzed. The majority of these patients had received primary treatment at institutions located nearer the front. Some reached the Head Center within a few days; others a week or two later. Here they were kept under observation and treatment until it was felt that they were well out of danger. Practically all injuries were incurred in the Italian campaign, from Salerno, in September, 1943, to, and including, the Anzio Beachhead, in mid-winter, 1944.

TABLE I  
TYPES OF MISSILES CAUSING WOUNDS

Shell fragments.....	66
Machine gun or rifle.....	10
Land mine.....	8
Aerial bomb.....	6
Mortar shell.....	3
Grenade.....	1
Flak.....	1
Revolver.....	1
Miscellaneous, or unknown.....	4
Total .....	100

*Wounding Agent.*—As may be seen in Table I, the missiles most frequently responsible were shell fragments. The majority of these were small, varying from 3 to 15 mm. in their largest dimension, and often multiple. Only ten wounds were due to machine gun or rifle fire; eight were caused by land mines, and six by aerial bombs. While the majority were known to have been wearing helmets at the time of wounding, exact figures are not available.

*First Aid.*—Almost all had had sulfonilamide powder and a dry dressing applied to the wound within an hour or two of the injury. It was impossible in most instances, however, to determine the elapsed time with accuracy, to learn just how much drug had been applied, or what wound toilette had been effected. Sulfonamide tablets were recorded as having been given in some instances, though this was the exception rather than the rule ahead of the Field or Evacuation Hospitals. Data relative to loss of consciousness and amnesia were insufficient for statistical study.

*Convulsions.*—In view of the fact that most of these wounds involved the cerebrum, it was of interest that convulsions were quite uncommon in this echelon, *i.e.*, during the first few weeks after wounding. Excluding cases of meningitis, but five patients experienced convulsions. All of these were associated with some degree of motor weakness, and were jacksonian in

type. In one patient whose left occipital lobe wound had been incompletely débrided, convulsions which began in the right face, were the most prominent early manifestations of an occipital lobe abscess. A second individual had a few minor convulsions confined to the left face prior to the débridement of a wound in the right temporal lobe. A third patient suffered three minor left-sided attacks during the second week following débridement of a right temporal lobe wound. A fourth patient developed weakness and repeated seizures which began in the right hand, arm, and face following a wound low in the left frontoparietal region. After primary incomplete débridement, strength gradually returned, and the convulsions ceased. Reappearance of jacksonian convulsions of the same type, together with occasional mild headaches and photophobia, marked the development of a small subcortical abscess about a retained bone fragment.

*Subdural hematoma* occurred but twice in this series. In one case right parieto-occipital subdural hematoma was associated with an overlying pavement fracture. Improvement followed early evacuation. However, persistent lower quadrantic left homonymous hemianopsia led to an encephalogram seven weeks later. This disclosed a right parietal lobe porencephalic cyst of irregular contour which extended from the cortex to the lateral ventricle. The coexistence of subdural and subcortical hematomas was thus suggested. In the second patient a right frontal subdural hematoma of 30 to 40 cc. followed a penetrating flak wound of the underlying lobe. Recovery followed wound débridement and evacuation of the hematoma. In no case was extradural hemorrhage extensive.

*Wound Infections.*—By far the greatest problem connected with the treatment of compound, comminuted fractures of the skull at this echelon was infection. All told, 41 of the 100 head wounds failed to heal *per primam*. Among these were 22 deep infections, manifested by abscess, fungus, meningitis, or some combination thereof. In this group occurred the only five deaths of the series. The remainder of the infections, or 19, were limited to the extracranial wound. The prevention, early recognition, and treatment of head wound infections are thus matters of importance, second only to the initial control of hemorrhage and of increased intracranial pressure.

In studying the healing of such wounds, it is well to bear in mind that certain factors of great importance must of necessity remain indeterminate. These, in particular, are: the degree of initial soiling, the extent and amount of local tissue necrosis, and the surgical technic subsequently practiced. Those who have seen Evacuation and Field Hospitals in action will readily understand that operating conditions cannot always be ideal.

*Time Factor.*—Elapsed time between wounding and operation varied from a few hours to four days. The average lag for those wounds which healed by first intention was 19 hours, while for the group with infections it was 29. Delay of one or two days should by no means preclude wound débridement and tight closure. This is attested by the fact that this procedure was successfully carried out on a number of occasions three or four days after

injury. Obviously, however, the earlier the operation can be performed the better, the patient's condition and local facilities permitting.

*Sulfonamide therapy* was employed in the majority of cases. Its effect on the incidence and spread of wound infection was difficult to assess since we observed no comparable group of cases not so treated. Owing to the smallness of the series, and the fact that some records were inadequate, little more than a hint could be obtained relative to the value of local *versus* general use of the drug (see Table II). Of 67 patients definitely recorded as having received sulfonamide therapy either locally or generally, 29, or 43 per cent, developed wound infections. It is obvious that proper surgery

TABLE II  
69 PATIENTS DEFINITELY RECORDED AS HAVING RECEIVED SULFONAMIDE THERAPY

	Healed Per Primam	Infected	Total
Local use only.....	18	13	31
General use only.....	9	10	19
Local plus general use.....	11	6	17
None.....	2	0	2
Total.....	40	29	69

is still prerequisite to sound wound healing. Penicillin was not available during this period.

*Primary Débridement.*—The general policy was to excise badly contused portions not only of scalp and bone, but of brain tissue as well. As far as possible, all dirt, hairs, bits of helmet and other foreign matter were removed. Metallic foreign bodies were extracted where accessible, provided their

TABLE III  
EFFECTS OF INDRIVEN BONE FRAGMENTS ON WOUND HEALING

	Healed Per Primam	Superficial Infection	Deep Infection	Deaths	Total Infections	Total
All fragments removed at primary débridement.....	34	9	2	0	11	45
Part, or no fragments removed at primary débridement.....	19	10	20	5	30	49
Total.....	53	19	22	5	41	94

removal did not involve injury to important neural structures. Since indriven chips were nearly always present in this type of penetrating skull wound, their presence after operation (as demonstrated roentgenologically) was taken as an indication of the measure of completeness of débridement.

*Results.*—Of the 94 patients with indriven bone fragments, the wounds in 53 healed *per primam*, while the remaining 41 failed to do so. In most instances this was due to infection. The value of thorough débridement may be seen in Table III. When complete, the majority of wounds healed by first intention; such infections as occurred were for the most part superficial. On the other hand when the wound was débrided incompletely, or not at all, infection followed more often than not (in 30 of 49 cases). Moreover, the majority of the infections in the latter group were deep seated. Among them occurred all five deaths. Inadequate débridement was the largest single factor contributing to infection.



*Tripod incisions* gave trouble in the majority of cases. Thirteen of the 18 in this series failed to heal *per primam*, due to apical necrosis, to infection, or to both. If an additional eight examples seen in the Head Center be considered, it is found that 18 of the 26 broke down. While the trouble could not be ascribed to the type of incision in each instance, it has been sufficiently common as to suggest that the tripod incision be avoided when

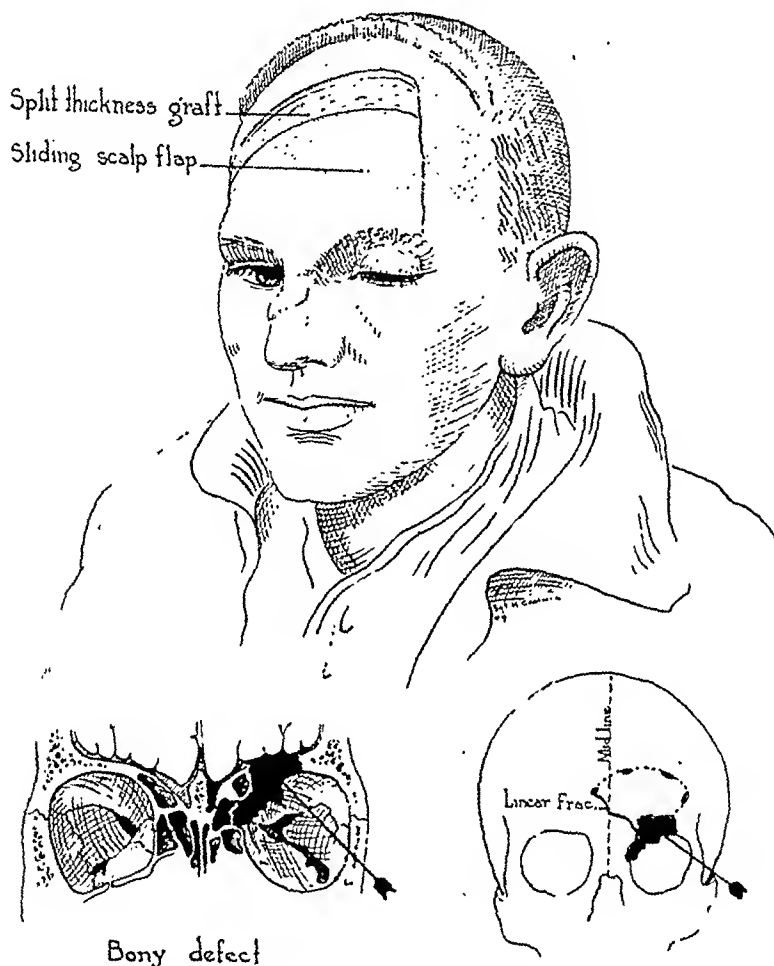


FIG. 1.—One method of replacing a large area of scalp loss by a sliding flap. In this patient the skin defect was near the brow. The denuded area above was covered with a split thickness graft. (Case of Major C. E. Downman)

possible. On the other hand, it is a convenient and sometimes unavoidable means of exposure. Occasionally one finds it ready made. Cushing used it, or its Isle of Man modification, with success in the last war. When employed, acutely-angled flaps should be avoided, and the narrowest angle placed on the side of the best blood supply. Great gentleness should be exercised in handling the flaps, particularly their apices. If apical sutures are necessary, they must be tiny and nonconstricting. Accurate closure without tension is essential. Hence, if there has been much loss of scalp tissue, the flaps must be made rather long and even converted into the Isle of Man form, in order to gain sufficient mobilization. Tension is thus avoided, or decreased, by taking advantage of the elasticity of longer skin flaps.

If the area of scalp loss be such as to preclude the use of a simple linear or curvilinear incision, a method which has been employed with success is that of a generous-sized flap, with the wound defect in its center. When débridement has been completed, the wound of entry is accurately closed, the flap then sutured back, with a wider distribution of the resulting tension. The latter, if significant in degree, can be entirely avoided by placing a split-thickness graft in the crescentic defect at the unsutured apex of the flap.

Inner table depressions are easily overlooked; together with pavement depressions they made up 15 per cent of this group of cases. Tangential injury from a rapidly travelling missile may produce a fracture in the outer table difficult to detect, yet displace fragments of inner table considerably. Whether or not the dura is torn, serious trouble may follow wound infection. The following case is particularly interesting in that an apparently minor scalp wound lead to almost catastrophic complications:

**Case 1.**—A 21-year-old male was struck a glancing blow in the right frontal region by a rifle bullet at 1800 hours on November 7, 1943. He was momentarily unconscious. Sulfanilamide powder was sprinkled into the wound and a dry dressing applied in an Aid Station. At an Evacuation Hospital the next day, the wound was inspected, no fracture observed (roentgenologic examination of the skull was reported negative), and the skin sutured. From November 10, 1943, to November 12, 1943, there was fever of 102° F. to 103° F. and purulent wound drainage for a few days. He was subsequently evacuated through four different installations, the last of which was reached on November 18, 1943. There the temperature was found to be 104.2° F. (R); pulse 110; and respiration 30. Drowsiness, cervical rigidity and dehydration were pronounced. He was incontinent of urine. All deep reflexes were diminished. The white blood count was 23,000, and the red blood cell count 3.5 millions. Lumbar puncture was reported to have disclosed cloudy fluid under low pressure. Sulfadiazine therapy was instituted. On November 21, 1943, he was still drowsy, but rational. Two left-sided jacksonian convulsions occurred that day, each beginning in the face, and involving that entire side of the body, plus the right face, as well. Lumbar puncture then yielded cloudy fluid under a pressure of 220 mm. of water, with white cell count 1,500. Further analysis of this specimen disclosed: glucose 44 mg./100 and globulin 1+; both smear and culture were negative for bacteria. During the next two days fever and cervical rigidity continued, while convulsions became increasingly frequent and severe.

On admission to the Head Center, November 22, 1943, the patient was drowsy, but rational. He complained of severe headache and his neck was rigid. Temperature 101° F.; pulse 60; and respiration 16. The small right frontal scalp wound appeared healed save for a small central crust. Neurologic examination revealed left flaccid hemiplegia, and left hemihypalgesia, with complete asteriognosis in the left hand. There was complete left homonymous hemianopsia to repeated rough testing. The right pupil was slightly smaller than the left. The retinal veins were quite full, but the nerve heads were not swollen. The left abdominal reflexes were absent. Sustained ankle clonus was found on the left side. Examination of the eardrums was essentially negative. Roentgenologic examination disclosed a small comminuted fracture beneath the right frontal wound with slight depression of the inner table. The preoperative diagnosis was meningitis, and right intracerebral abscess.

**Operation.**—November 22, 1943: Under local anesthesia, the scalp incision was lengthened and reopened. The wound contained a small amount of granulation tissue but no pus. There was no edema of the nearby scalp. When the periosteum was retracted careful inspection revealed a faint circular crack. In the center the bone was

definitely pale. When a perforator opening was made nearby, 10 to 15 cc. of light yellow pus escaped under pressure. After the fracture had been isolated by rongueering, the depressed inner table (Fig. 2) was found lying in an extradural bed of pus and granulation tissue. The dura was not torn. Surrounding bone was removed until white dura was everywhere exposed.

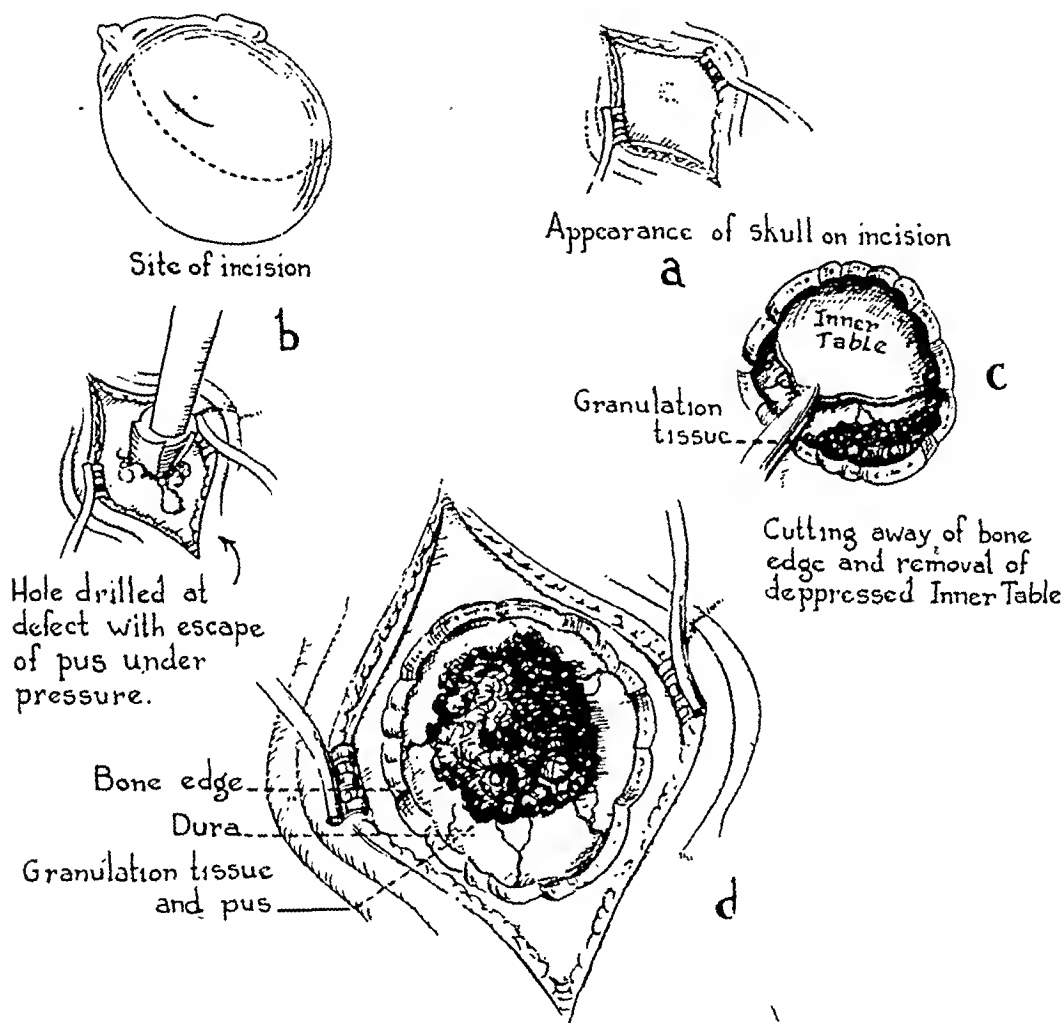


FIG. 2.—Case 1: Drawing showing steps taken to unroof and evacuate extradural abscess.

Owing to the presence of left-sided hemiplegia, hemihypalgesia and left homonymous hemionopsia it was felt that an intracerebral abscess must exist. When a tiny nick was made through an iodized area of clean dura, several cubic centimeters of cloudy subdural fluid escaped. The small area of arachnoid visible resembled that usually seen in purulent meningitis. A ventricular needle was inserted into the frontal and temporal lobes with negative findings. The dural opening was closed with a single fine silk suture. The scalp was then sutured with silk. Sulfathiazole was given parenterally in amounts sufficient to maintain a high blood level.

Wound cultures yielded *aerobic hemolytic Streptococci*.

Convalescence was surprisingly rapid, and save for one convulsion confined to left face the day following operation, uneventful. There was a small amount of wound drainage, but this ceased within ten days. Strength and sensation returned rapidly in

the leg, arm and lastly in the fingers. The hemianopsia cleared more slowly, although within three weeks the fields had filled out about half way. A letter from him, written three months after operation, stated that he felt quite well.

COMMENT.—From the rapidity and completeness of recovery it would appear altogether unlikely that this patient had an intracerebral abscess. The left hemiplegia, hemihypalgesia and homonymous hemianopsia could be explained in the basis of right hemispheric cortical inflammation, in which the cloudy subdural fluid may have played a rôle. (Unfortunately none of it was collected for study.) Similar neurologic changes were recently observed in a soldier with chronic right-sided mastoiditis and lateral sinus thrombosis. When first admitted with meningitis until he became comatose two or three days later, left hemiplegia, hypalgesia and homonymous hemianopsia were present. Autopsy revealed, in addition to meningitis, a mat of thick subdural pus over the posterior two-thirds of the right hemisphere. It was particularly heavy over the lateral and medial surfaces of the right occipital lobe.

*Dural Closure.*—There is no general agreement regarding the value of dural suture at the time of primary débridement. Some neurosurgeons feel that by leaving the dura open, pus and necrotic tissue may escape, and hence the incidence and severity of deep infection be lessened. Closure was not effected in the majority of the cases of this series. It is difficult to know whether or not any of the extracranial infections actually originated intracranially, and serious complications were thus prevented by the dura having been left open. On the other hand, no instance of spontaneous evacuation of pus or necrotic tissue from beneath the dura was observed. The only possible exceptions were the five cerebral fungi unassociated with abscess or meningitis. It could equally well be argued that these herniae might not have occurred had the dura been closed; in any case their formation was of doubtful benefit! On the other hand, there were at least three cases in which dural closure by fascial graft successfully confined infection to the extracranial wound. Brief abstracts of these cases follow:

Case 2.—A male received a compound, comminuted fracture in the left anterior temperoparietal region when a shell burst overhead at 1,600 hours, on November 22, 1943. He was wearing a helmet at the time. Consciousness was not lost. Although unable to speak or to move the right hand and arm, he managed to walk to an Aid Station more than a mile away. Twelve hours later the wound was débrided, and bits of helmet, shell fragment, bone, pulped brain tissue and blood clot were removed. The dural rent was closed with a graft of temporal fascia. Sulfonilamide powder was sprinkled into the wound, and the skin closed without drainage.

Speech as well as strength in the right hand soon began to return. Two jacksonian seizures occurred on December 1 and 2, 1943. The incision was said to have healed, although when admitted to the Head Center on December 26, 1943, the wound was open and draining profusely. *Aerobic hemolytic Streptococci* were cultured from the pus. The scalp over the bony defect was pulsating normally and there were no symptoms suggestive of increased intracranial pressure. Despite the presence of rather active infection separated from the brain only by a fascial graft, neurologic signs rapidly decreased. Two weeks later when the wound had healed, speech was entirely normal, as was strength in the right hand and arm. Agraphia, which had been present soon

after injury, had completely disappeared, and only slight asteriognosis remained in the right hand.

**Case 3.**—A young male was struck in the right forehead by a machine gun bullet at 1,230 hours on October 27, 1943. He was rendered unconscious immediately. Sulfonilamide powder and a dry dressing were applied at an Aid Station. When examined at an Evacuation Hospital, eight hours later, he was awake and coöperative. The

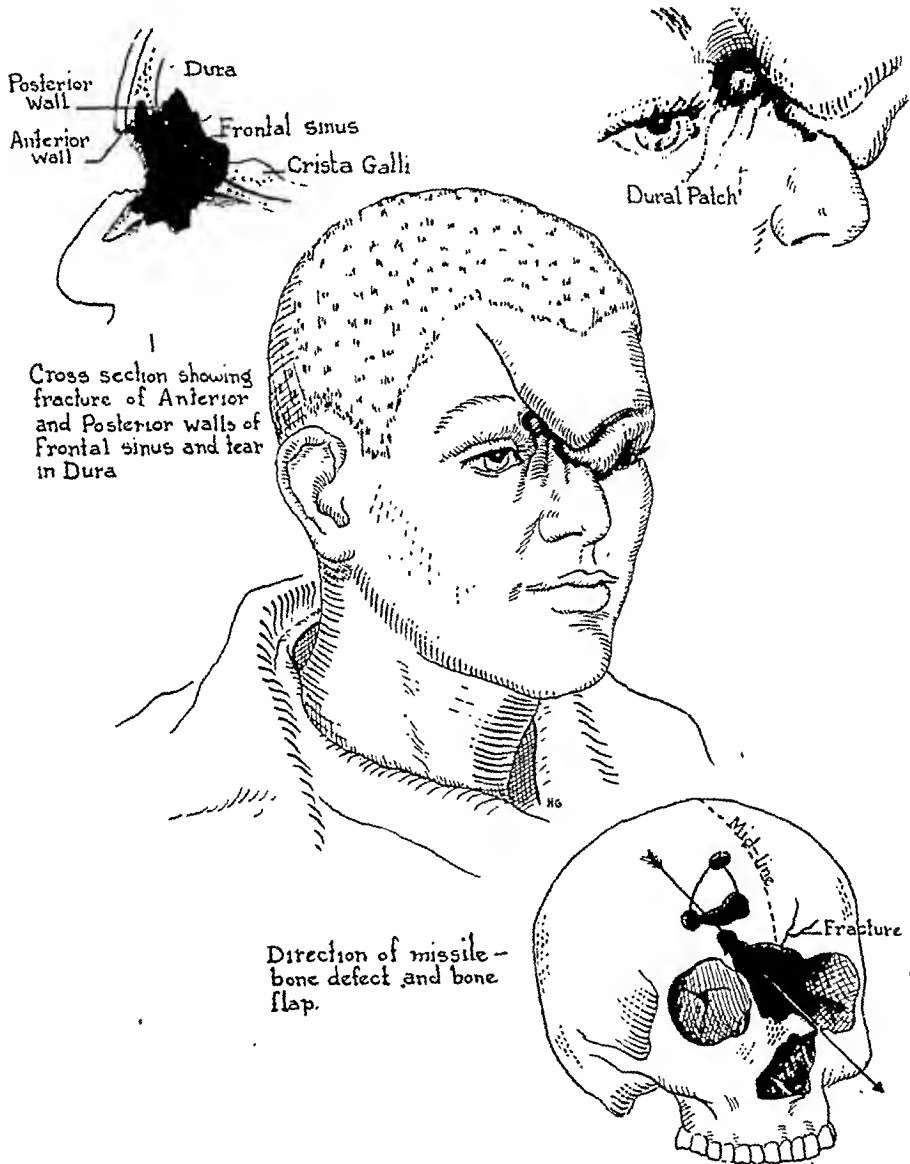


FIG. 3.—Case 3: Drawing depicting partially healed gutter wound of right frontal lobe, frontal, and ethmoidal sinuses and nose. The dural patch was still visible when this sketch was made, two months after injury.

wound was of the gutter type and extended from the right forehead to the left cheek. The frontal and anterior ethmoidal sinuses were laid open widely. The tips of both frontal poles were injured, while all tissue in the region of the nasion and glabella had been shot away. Pulped brain tissue, blood clots and cerebrospinal fluid filled the wound. Vision in the right eye was limited to light perception. No other neurologic changes were found.

**Operation.**—October 18, 1943 (18 hours after injury): The wound was carefully

## COMPOUND, COMMINUTED SKULL FRACTURES

débrided. The huge dural defect was repaired with a graft of fascia lata. As a result of extensive skin loss only the upper portion of the wound could be closed. The fascial graft was thus of necessity left widely exposed through the open frontal and ethmoidal sinuses. Sulfonilamide powder was sprinkled into the wound and sulfadiazine was administered orally.

Convalescence was remarkably uneventful. When admitted to the Head Center, November 9, 1943, an area of fascial graft, approximately 2 cm. in diameter, was exposed (Fig. 3). Granulation tissue was observed to be growing in from all sides. Within the next eight weeks not only the graft but the entire defect had been covered externally with epithelium.

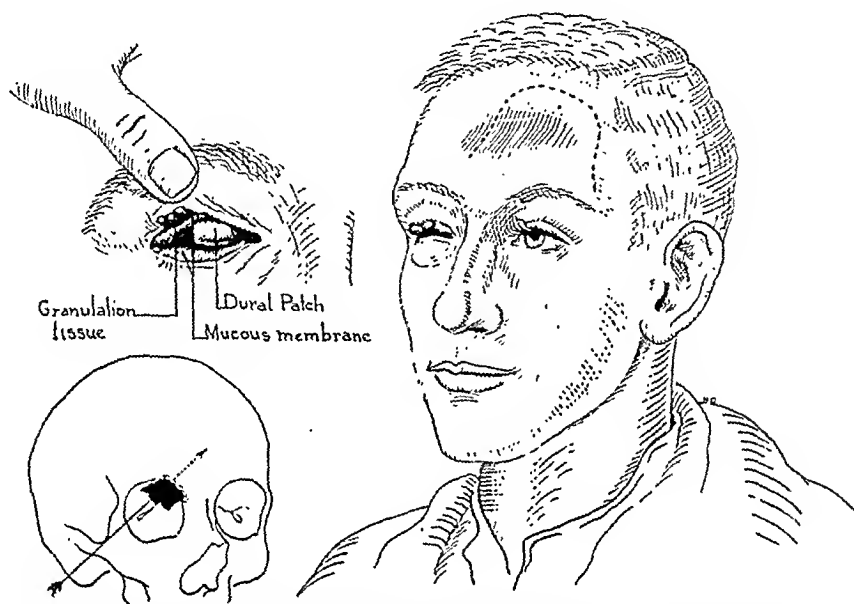


FIG. 4.—Case 4: Penetrating wound of right orbit, with destruction of eye, orbital roof, dura, frontal and ethmoidal sinuses and pole of left frontal lobe. Large dural defect repaired with fascia lata, as shown in inset 5 weeks later. (Case of Major C. E. Dowman)

COMMENT.—In this case a fascial graft afforded the sole protection to an otherwise exposed brain. That this is not an isolated result was demonstrated by a second patient (Case 4) in which both contents and roof of the right orbit had been shot away. Both frontal and anterior ethmoidal sinuses were traversed by the missile, which was removed from the left frontal lobe, 28 hours later. After débridement the large dural defect in the roof of the right orbit was closed with fascia lata. Convalescence was uneventful. When admitted to the Head Center 17 days later not only had the scalp incision healed but the graft visible through the roof of the orbit was partially covered with clean granulation tissue (Fig. 4). When evacuated two months later healing was practically complete.

While dural suture is not essential in the treatment of the majority of penetrating brain wounds, it may at times prove of definite value. Although a fascial graft may not survive an adjacent infection and have to be removed, no case was observed here in which its presence appeared to have been harmful. Dural closure is, therefore, recommended.

*Deep Infections.*—Abscess, cerebral fungus, meningitis, or some combination thereof, occurred in 22 of the 41 infected wounds. Abscess was present

TABLE IV

BACTERIAL FLORA OF WAR WOUNDS \*(September 12, 1943 to March 1, 1944)

## CASE INCIDENCE

Species	Head	Extremity Lower	Extremity Upper	Face and Neck	Mis- cellaneous†	Cutaneous Ulcers
<i>Aerobic nonhemolytic Staphylococcus albus</i>	16	60	16	7	61	46
<i>Aerobic hemolytic Staphylococcus albus</i> ...	7	15	7	1	10	18
<i>Anaerobic nonhemolytic Staphylococcus albus</i> .....	0	8	0	0	2	1
<i>Anaerobic hemolytic Staphylococcus albus</i> ..	0	0	0	0	0	0
<i>Aerobic nonhemolytic Staphylococcus aureus</i>	0	0	0	0	5	3
<i>Aerobic hemolytic Staphylococcus aureus</i> ...	0	0	0	1	0	0
<i>Aerobic nonhemolytic Streptococci</i> .....	5	20	2	1	6	4
<i>Aerobic hemolytic Streptococci</i> .....	5	35	11	7	25	40
<i>Anaerobic nonhemolytic Streptococci</i> .....	1	4	0	0	2	0‡
<i>Anaerobic hemolytic Streptococci</i> .....	0	6	0	0	2	0§
<i>Streptococcus viridans</i> .....	0	0	1	0	1	1
<i>E. coli</i> .....	1	6	1	0	2	2
<i>A. aerogenes</i> .....	0	13	0	0	14	2
<i>E. coli</i> and <i>A. aerogenes</i> .....	1	25	1	0	0	0
<i>Clostridia</i> .....	1	25	1	0	1	0
<i>Proteus vulgaris</i> .....	1	8	3	0	8	0
<i>Pseudomonas pyocyanea</i> .....	0	7	0	0	5	1
<i>Corynebacterium diphtheriae</i> .....	0	0	0	0	0	20
<i>Diphtheroids</i> .....	1	14	3	1	1	15
Total number of cases with positive culture.....	23	105	28	22	62	111
Total number of cases with negative culture.....	2	5	3	0	0	0

\*420 cultures from 250 cases of war wounds; 140 cultures from 111 cases of cutaneous ulcers.

†Cases include wounds of the chest, abdomen, back and those in which the site of the wound was not indicated.

‡Includes two strains which formed gas and occurred in wounds harboring *Clostridia perfringens*.

§One strain only was micro-aerophilic; remainder were strict anaerobes.

17 times, cerebral fungus ten, and meningitis nine. It is worthy of note that in seven cases the scalp wound had healed *per primam*. Deep infections often smouldered for days or even weeks before producing symptoms. This was quite possibly due to the fact that the infecting organisms (see below) were often of low virulence.

**Bacteriology.**—Approximately 50 cultures were made on 25 cases. Bacteria were isolated from the wounds of 23. Sterile cotton swabs impregnated with material from the wound were placed in tubes of brain-heart infusion broth (Difco), alone and containing sodium thioglycollate for both aerobic and anaerobic cultures. Human blood-agar media was also inoculated. The bacterial flora isolated were identified by further accepted standard methods. Table IV summarizes the species of bacteria found resident in the wounds of the 23 cases. These micro-organisms may be compared with those contemporarily found in wounds in other portions of the body.

The bacterial flora of these wounds of the skull showed a significant incidence of contamination with inhabitants of the skin—the staphylococci.

There was a small number of common bacterial residents of the oral and respiratory passages, such as pneumococci, streptococci and diphtheroids. Rarely were micro-organisms associated with soil or fecal contamination, *i.e.*, the *Coli-aerogenes* group and the *Clostridia*, observed. This is in contrast to the bacterial flora observed in 110 cases of wounds of the lower extremity in which members of the *Coli-aerogenes* group and *Clostridia* were most frequently isolated (see Table IV). Anaerobic bacteria were practically non-existent in this group of skull wounds, whereas, quite the reverse was found to be true in the leg and thigh.

*Staphylococcus aureus* and *Streptococcus viridans* occurred surprisingly infrequently in this series. Strains of staphylococci were classified by their color on blood-agar after 48 hours incubation aerobically at  $36^{\circ}\text{C.} \pm 1^{\circ}$ . The significance of the appellation "*albus*" and "*aureus*" should be judged accordingly. The absence of streptococci producing a greening of human blood-agar media is in accordance with the infrequent occurrence of bacteria which inhabit the oral and nasal passages.

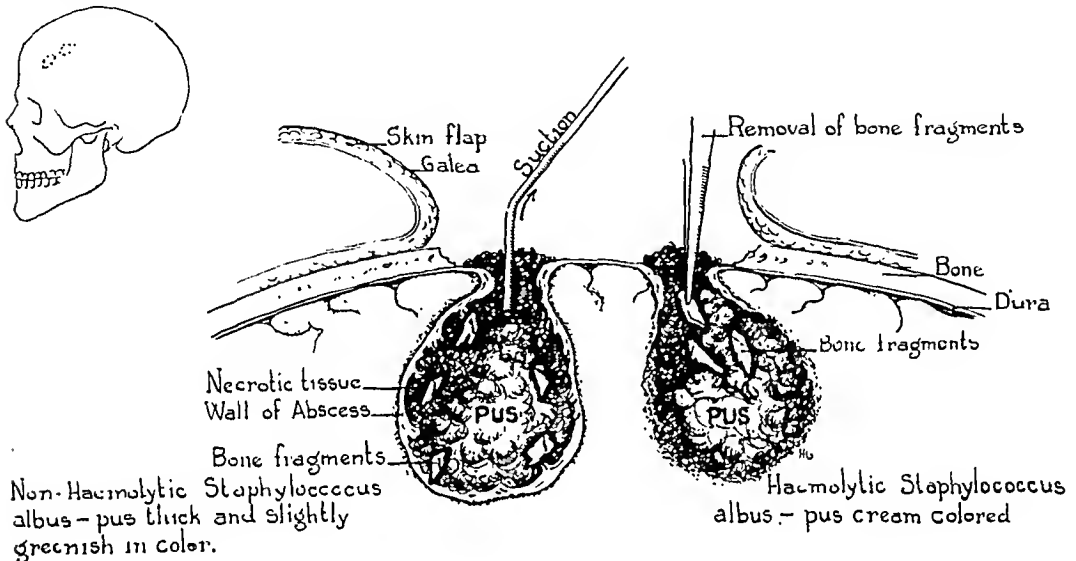
*Abscess.*—As a rule, the earliest symptom of abscess formation was headache. While the pain was by no means always severe, it was recurrent, usually at shorter and shorter intervals. Usually, also, it was unilateral and frequently awoke the patient from his sleep. Decreased or absent pulsation in the scalp flap became apparent later. Lumbar punctures were employed diagnostically when meningitis was suspected. All abscesses were associated with retained bone fragments and/or metallic foreign bodies. Roentgenologic demonstration of their presence after the primary débridement, therefore, should put one on guard. As has been pointed out by Ascroft, infection is particularly likely to occur where a dense cluster of chips is present within the brain. On two occasions (Cases 6 and 8) a metallic foreign body has been observed to rotate or change position; in each instance it lay free within an abscess cavity. The appearance of, or slight increase in, preëxisting neurologic signs during convalescence should make one very suspicious of deep infection. Neither fever nor leukocytosis was a prominent manifestation of early abscess.

In contrast to the predominance of common skin inhabitants among mild infections, bacteria responsible for the majority of abscesses were of greater virulence. Of seven strains of *hemolytic Staphylococcus albus* recovered from all wounds, five were associated with abscesses; the same was true for five of the six *hemolytic Streptococci*, and four of five *nonhemolytic Streptococci*. This group included most of the more serious infections. On the other hand, but five of 16 strains of *nonhemolytic Staphylococcus albus* were recovered from abscesses. Micro-organisms usually considered as soil or fecal contaminants, such as the *Coli-aerogenes* group and the *Clostridia*, and those customarily found in oral and nasal secretions, pneumococci, *streptococcus viridans*, and diphtheroids, were significantly infrequent.

Abscesses in this series were not strictly comparable to those customarily seen in connection with paranasal sinus or mastoid infection. All were



associated with intracerebral foreign bodies, such as chips of bone or pieces of metal. Bone fragments sometimes lay freely within the cavity, but more often were partially embedded within the abscess wall. Necrotic brain tissue and extravasated blood in the neighborhood of the abscess, not only served to increase the intracranial pressure, but afforded ideal media for extension of the infection. Abscess walls were thickest near dura; at some distance they might be thinner, incomplete, or unformed when observed within a few weeks of the injury. As seen at this time, the majority of the cavities were not large, probably averaging not more than 10 or 15 cc. capacity.



### TWIN SUBCORTICAL ABSCESSES

FIG. 5.—Case 5: Closely adjacent abscesses following penetrating wounds of left parietal lobe. One cavity had a tough capsule, while in the other there was little or no evidence of encapsulation. *Non-hemolytic Staphylococcus albus* was cultured from the first and *hemolytic Staphylococcus albus* from the second.

That the type of organism plays an important rôle in the process of the encapsulation is suggested by the following case in which abscesses developed in closely adjacent wounds. One was encapsulated, the other not; the former was infected with *aerobic nonhemolytic Staphylococcus albus* while the latter contained *aerobic hemolytic Staphylococcus albus*.

**Case 5.**—A young male, with a gunshot wound of the leg, was wounded in the head, November 8, 1943, when his ambulance was strafed by an enemy plane. The two left frontal wounds were débrided through a single linear incision, in a British Casualty Clearing Station ten hours later. Badly contused skin edges, bone chips and pulped brain tissue were said to have been removed. Sulfonilamide powder was dusted into the wounds, and the skin then closed with silkworm gut. Three grams of sulfadiazine was administered intravenously daily for several days. A few days later, in another hospital, he was observed to have right facial weakness and partial aphasia.

When admitted to the Head Center, November 24, 1943, he had no complaints. Slight right facial hypotonia was noted but speech was apparently normal. There was no other abnormal neurologic finding. Both frontal wounds had been débrided through a single incision, which was then healed and not bulging. Roentgenologic examination disclosed multiple small bone fragments beneath each of the two frontal bone defects.

Two days later a small amount of purulent drainage was noted from the incision. Secondary wound débridement was carried out under local anesthesia, December 7, 1943, 29 days after injury. A sinus tract leading to the anterior wound was excised, and the soft tissues widely retracted. The bone defects were closely adjacent, each was bulging with granulation tissue. Beneath the posterior opening an abscess cavity (Fig. 5), approximately  $5 \times 3 \times 2$  cm., was encountered. The supernatant pus was thick and creamy while the remainder was thinner and of a brownish color. Several bone chips lay within the cavity—unattached. Cultures from this abscess revealed *aerobic hemolytic Staphylococcus albus*.

When the anterior defect was entered, a well-encapsulated abscess, approximately  $5 \times 4 \times 3$  cm., was encountered. The pus was thick and of a greenish-yellow hue. A few bone chips were free, but the majority were adherent to, or embedded within, the thick wall of the cavity. No communication could be found between the two abscesses. Cultures from this abscess revealed *aerobic nonhemolytic Staphylococcus albus*. A small Penrose drain was left in each cavity, and the scalp closed with interrupted sutures of fine silk.

Convalescence was uneventful. There was practically no discharge, the drains were removed after 48 hours, and the wound healed *per primam*. When evacuated a month later, the scalp overlying the defects was sunken in, and pulsating well. No neurologic disturbances were present, save for mild right facial hypotonia.

Tardy encapsulation is not characteristic of all strains of the *hemolytic Staphylococcus albus*, however, as demonstrated by the following case:

**Case 6.**—A 29-year-old male was struck by shell fragments in the left anterior parietal region at 0600 hours on January 21, 1944. When admitted to a British Casualty Clearing Station he was semistuporous, aphasic, and unable to move the right arm. Roentgenologic examination disclosed several bone fragments beneath a compound, comminuted fracture of the left parietal bone. A large metallic foreign body was visible just beyond the midline. Eighteen hours after injury the wound was débrided, several bone chips, some clots and pulped brain tissue were removed. The large metallic foreign body was left behind. Sulfanilamide powder and flavine were said to have been implanted in the wound.

Following operation he improved rapidly. Both speech and strength in the right hand and arm began to return, headaches disappeared and the incision healed nicely. When admitted to the Head Center, February 7, 1944, he appeared to be convalescing satisfactorily. The scalp over the defect was soft and pulsating well, the incision appeared clean and he complained of no headaches. Speech was slow and painstaking, but error free. Positive neurologic findings were right hemiparesis, with hyperactive deep and diminished abdominal reflexes on that side. Position sense and interpretation of figure writing were impaired in the right hand. Slight papilledema was noted bilaterally.

Four days later the wound appeared somewhat swollen and tender, and it was thought that the right hand had become weaker. On February 13, 1944, it was quite evident that the right hemiparesis was increasing. Motor aphasia became rather marked. He had several headaches, one or two of which had awakened him from sleep. Pulsations in the flap were decreased. Roentgenologic reexamination disclosed two small bone fragments beneath the defect. Of considerable interest was the fact that the metallic foreign body had shifted position since the taking of the first films. While it was realized that it might have been moved by the first operator, it was thought more likely that it lay within a fluid-filled cavity. It was not in the position of the ventricle, and, indeed, would have been too large to move freely therein. This served to corroborate the diagnosis of abscess.

FIG. 6A



FIG. 6B

FIGS. 6A and B.—Case 6: Lateral and postero-anterior roentgenograms of skull showing compound, comminuted fracture of left parietal area with indriven bone fragments. Note the large metallic foreign body lying just beyond the midline.

## COMPOUND, COMMINUTED SKULL FRACTURES

On February 14, 1944, 24 days after injury, the wound was reopened under local anesthesia. Immediately beneath the defect 10-15 cc. of necrotic brain tissue was found and removed. The larger of the two bone chips was partially embedded in the wall of a well-encapsulated abscess (Fig. 6). Approximately 66 cc. of light-yellow pus was evacuated. The second bone fragment and the metallic foreign body lay free within the cavity, the latter at the medial pole. Both were removed. The scalp was closed loosely around a small Penrose drain. *Aerobic hemolytic Staphylococcus albus* was the sole organism cultured from the pus. The drain was removed in 48 hours. There was no drainage before or afterwards.



FIG. 7A



FIG. 7B

Figs. 7A and B.—Case 6: Lateral and anteroposterior roentgenograms taken before secondary débridement, showing change of position of the metallic foreign body. Two small bone fragments are visible.

Convalescence was slow but satisfactory. Within six weeks the speech disturbance had largely cleared, he walked without a limp, and strength and sensation in the right upper extremity were greatly improved. The flap was soft, sunken, and pulsated normally.

*Cerebral Fungus.*—This occurred in ten cases. Three were associated with abscess and meningitis, and were fatal. One arose in association with a wound infection and abscess while another occurred in the presence of wound infection and meningitis; both of these patients recovered. Five cerebral herniae were not associated with abscess or meningitis, and all healed. It was of interest that in but two of this last group of cases was the fungus of the rapidly progressive type, requiring débridement. One of these followed an untreated perforating revolver wound, extending from the left eye to the left occiput. The other, a German prisoner, suffered a perforating wound

extending from the right frontotemporal to the right occipital region. On admission to the Head Center, 15 days later, a large rather firm fungus protruded from the wound of exit. When excised, its core was found to be yellowish-red in color and rather tough in consistency. A mixed infection of *aerobic nonhemolytic Staphylococcus albus*, *Coli-aerogenes* and *Clostridium septicum* was found in the wound. He recovered without further complication.

Organisms cultured from fungi were for the most part skin inhabitants of low virulence. *Aerobic nonhemolytic Staphylococcus albus* were present in five, *aerobic hemolytic Staphylococcus albus* in two, *aerobic hemolytic Streptococcus* in one, and in another, the mixed infection mentioned in the

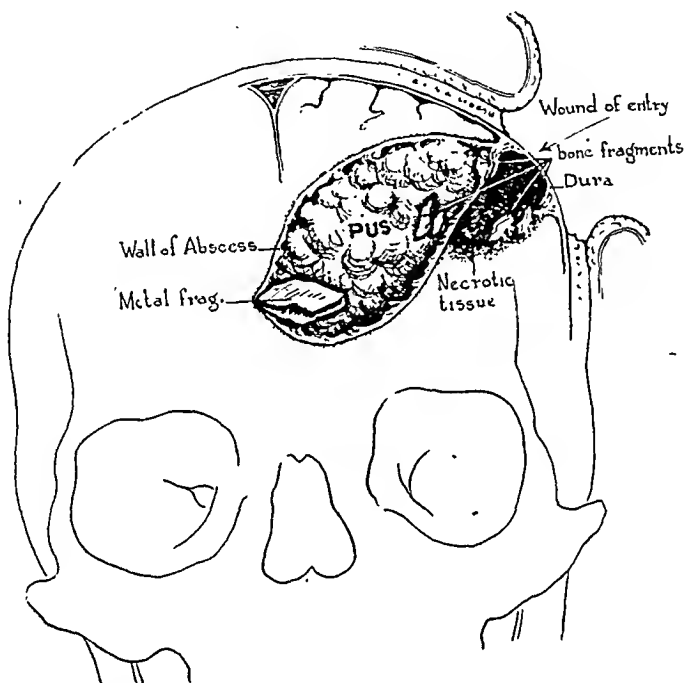


FIG. 8.—Case 6: Drawing showing metallic foreign body and two bone fragments lying free within cerebral abscess. One piece of bone is partially embedded in thick wall of abscess. Note adjacent area of necrotic tissue.

preceding paragraph. Bacteriologic studies were lacking in the remaining three. Had more virulent organisms been present it is likely that the infections would have been more difficult to cope with.

*Meningitis.*—This occurred as a complication of wound infection in nine patients. There were five\* fatalities, all of which were associated with abscesses which were undiscovered or evacuated too late. Of the four survivors, one developed meningitis due to an *aerobic hemolytic Streptococcus* following an extradural abscess (Case 1). The other three occurred with wound infections, in but one of which there was a fungus.

Organisms identified in the wounds of patients who developed meningitis were: *Aerobic nonhemolytic Streptococcus* in three; *aerobic hemolytic Strep-*

\* Including the three referred to under cerebral fungus.

*tococcus* in two; *anaerobic hemolytic Streptococcus* in one; and *aerobic nonhemolytic Staphylococcus albus* in three. Two had mixed infections. In three cases laboratory facilities were temporarily unavailable.

*Treatment of Wound Infection.*—Superficial infections required little active treatment. Bone, metallic fragments and exposed silk (particularly if heavy) were carefully removed. Hot wet dressings were customarily employed. Sulfonamides were used generally, but not locally. In several instances infections occurred in comminuted fractures of the pavement-depression type. In these cases formal débridements, with removal of bone fragments, were carried out. Wound healing then followed in each instance.

*Deep Wound Infection.*—This was an infinitely more serious matter, both as regards mortality and further destruction of neural tissue. While thorough encapsulation of the infection would have been highly desirable, one's hand was usually forced by the rise of intracranial pressure, by the imminence or actual presence of meningitis or fungus, and of further destruction of adjacent cerebral tissue. Bone fragments and/or metallic foreign bodies were involved in the formation of every abscess. An effort was, therefore, made to remove them as well as to evacuate pus and necrotic tissue from within the cavity. Adjacent extracapsular clots and necrotic tissue were removed with the sucker or with cotton patties. The capsule of the abscess was, of course, left behind. Stalactitic bands of fibrous tissue extending inwardly from dural edges were disturbed as little as possible. Even with good stereoscopic roentgenograms available, thorough secondary wound débridement is not always an easy matter. Abscesses may be difficult to find because of their consistency, their size, or their unexpected locations. Air studies are sometimes necessary. This general plan of treatment was carried out during the Tunisian Campaign by some surgeons, with success.

Drainage of brain abscesses was employed only occasionally. When attempted, little or no pus escaped. If the secondary débridement had been adequate, drainage was unnecessary, while if inadequate, a drain did not suffice to clear up the infection. The following cases are illustrative:

**Case 7.**—A 30-year-old male was wounded in the left parieto-occipital region by shell fragments at 0230 hours, December 9, 1943. Consciousness was evidently lost soon afterwards, although he subsequently remembered being hit. On admission to an Evacuation Hospital five hours later, he was lethargic and partially aphasic but able to respond to simple commands. Spastic paresis was noted in the right arm and leg, and there was some right facial weakness. The deep reflexes were hyperactive on the right and a positive right-sided Babinski sign was present. The scalp wound was triangular-shaped, measuring 3 x 1.5 cm. Roentgenologic examination disclosed an underlying bone defect of similar size, with many small indriven bone fragments. Two metallic foreign bodies were seen just below the bone defect, a third deep in the left parietal lobe, while a fourth, and larger one, lay near the falx beneath the coronal suture. Primary wound débridement was performed under local anesthesia ten hours after injury. The wound was "débrided with suction and irrigation," some pulped brain tissue, a few bone chips and the two superficial metallic foreign bodies were removed. Dura, galea and skin were closed in layers with interrupted sutures of fine silk.

Improvement was rather slow. He suffered several jacksonian convulsions the

next three days. Some drowsiness, incontinence, and fever to  $101^{\circ}$  F. were present during this period. Speech was monosyllabic. Stitches were removed on the fifth postoperative day. Both then, and as late as December 22, 1943 (13 days after operation), the wound was noted to have been cleanly healed and not bulging.

When admitted to the Head Center, December 28, 1943, he complained of headache. The temperature, pulse and respirations were normal. The two-inch parieto-occipital incision was open and obviously infected. Nominal aphasia was noted. Answers were in monosyllables. No alexia nor apraxia was present; agraphia was not tested because of flaccid paralysis of the right arm. Astereognosis was observed in the right hand. Deep reflexes were hyperactive on the right side and positive Hoffman and Babinski reflexes present in the right. The left abdominal reflexes were relatively hypoactive. There was bilateral papilledema with fresh hemorrhages and exudates.

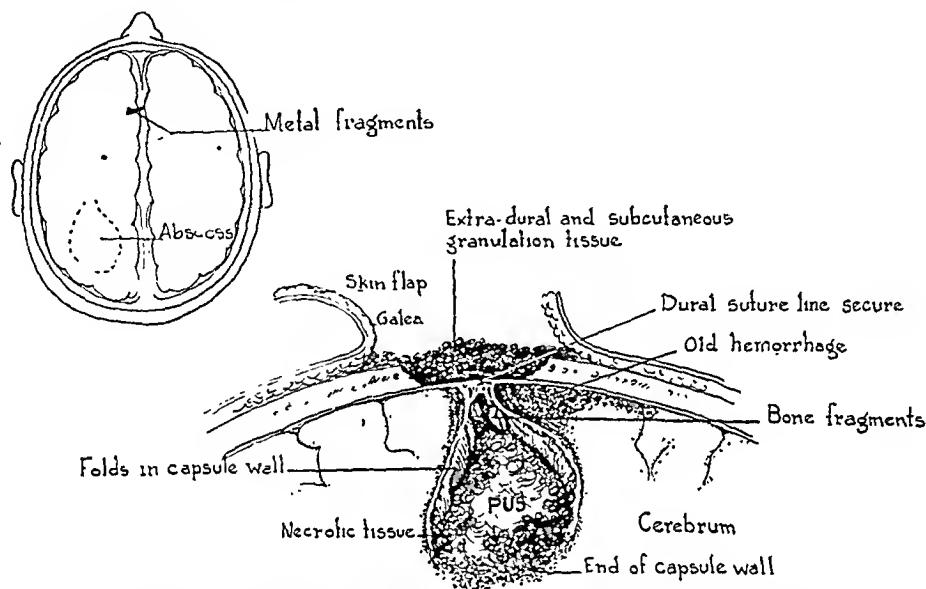


FIG. 9.—Case 7: Cerebral abscess following penetrating wound, left parieto-occipital lobe. Encapsulation incomplete. Dural suture line secure, three weeks after injury. Prompt healing followed secondary débridement.

**Laboratory Data.**—Roentgenologic examination revealed many small bone fragments beneath the defect. The two nearest metallic foreign bodies had been removed. The white blood cell count was 5,900, and the hemoglobin 12 Gm. (Sahli). The urine was normal. Wound smear disclosed numerous gram-positive cocci, subsequently identified as *aerobic nonhemolytic Staphylococcus albus*.

**Operation.**—December 29, 1943: Under local anesthesia, the wound was widely reopened, pus and granulation tissue being found down to the dura (Fig. 9). The latter had remained snugly closed but was tense, and not pulsating. The bone edges were rongueured away, and the dura then opened. A small collection of pus was encountered, and evacuated. This was walled-off on its dural side, the capsule having faded out at a depth of 2.5 cm. Necrotic tissue, old blood clot and several bone chips were then removed, leaving behind viable-appearing tissue. No attempt was made to extract the two distant metallic foreign bodies. Brain pulsations were fair at the end of the procedure. The scalp was closed in layers with interrupted sutures of fine silk without drainage. No sulfonamide was used locally, but sulfathiazole was administered by mouth, and a high blood level maintained.

By next morning improvement was evident. He could speak phrases of several words, and strength began to return in the right hand. It could then be discerned that agraphia was present. The wound healed *per primam*. Headaches gradually disappeared. When evacuated five weeks later there had been marked recovery of

strength as well as in his ability to speak, read, and write. The flap was soft and pulsated well. Papilledema, though still visible, was subsiding.

In contrast to the very satisfactory result of careful secondary débridement, performed 20 days after injury in the above case, the tragic effect of incomplete operation is shown in the next patient:

**Case 8.**—A 23-year-old male was struck by several shell fragments in the left occiput, right thigh and foot, at 1700 hours, October 13, 1943, in the Volturno River fighting. At an Evacuation Hospital the thigh and foot wounds were débrided and the tiny occipital wound covered with a dry dressing. On board a hospital ship, nine days later, he had a brief attack of meningitis, gram-positive diplococci having been found in the cerebrospinal fluid. When admitted to the Head Center, 11 days after wounding, he was alert, coöperative, and in good general condition. Cervical rigidity had disappeared, and he had no complaints. In the left occipital region there was an unhealed wound, approximately 2 cm. in diameter, which pulsated freely. The skin in this region was thin and depilated from a childhood burn. The thigh and foot wounds were of minor nature and healing well. No papilledema was present, but right homonymous hemianopsia was demonstrable. Vertical and horizontal nystagmus were noted in all ranges except directly forward and downward, the quick-component having been to the right. Deep reflexes were slightly more active on the right, and right leg movements were not as well coördinated as the left. No other neurologic changes were found. Roentgenograms of the skull disclosed extensive fracture with fragmentation in the left parieto-occipital region, and numerous indriven bone chips. A cluster of these lay about 2 cm. beneath the bony defect. A metallic foreign body, approximately 6 mm. in diameter, was visible in the left side of the posterior fossa, apparently lying against the medial end of the petrous pyramid. A second tiny metallic foreign body was observed 4 or 5 cm. beneath the wound. No bone chips were visible in the posterior fossa.

On November 9, 1943, he complained of headaches, and very early papilledema was observed in the left eye. The wound pulsated as before, but hemianopsia was more nearly complete. For the first time, some clumsiness appeared in the left arm, and in both lower extremities. Deep reflexes were equally active, no pathologic reflexes having been found. There was no fever nor cervical rigidity. Sulfathiazole therapy was given and an adequate blood level continuously maintained.

**First Operation.**—November 10, 1943 (31 days after injury): The bony defect was exposed under novocaine anesthesia through a vertical incision. A well-encapsulated abscess was found containing in its walls the cluster of bone chips, seen by roentgenogram. The cavity extended from the dural opening almost to the tentorium. It was thoroughly emptied of both pus and bone particles. A deep extension was sought for, but not found. A small Penrose drain was left within the cavity for 48 hours.

The wound healed promptly. During the succeeding ten days the patient appeared much improved, bright, cheerful and in no pain. On November 20, 1943, however, headaches reappeared, this time more severe, and accompanied by vomiting. Nystagmus, which had been continuously present, became more marked, while ataxia of the left arm and leg were conspicuous. Pulsation over the skull defect ceased. Restudy of the roentgenograms disclosed that the metallic foreign body in the posterior fossa had rotated between the taking of the successive pictures. This was interpreted to mean that it lay in a fluid medium. Obviously not being in the fourth ventricle, this could but confirm a belated diagnosis of left cerebellar abscess.

**Second Operation.**—November 21, 1943: Under endotracheal ether anesthesia, small left suboccipital opening was made, 3.5 cm. beneath the dura, an abscess was evacuated, containing 40-50 cc. of pus, from which *aerobic nonhymolytic Streptococci* were subse-



quently cultured. No abscess capsule was palpable. Repeated attempts to grasp the shell fragment were unsuccessful, and eventually abandoned. A small Penrose drain was left in.

Again, relief was but temporary. Two days later signs of rapidly mounting intracranial pressure led to reexploration of the occipital lobe abscess, the cavity of which contained little or no pus. Once more, the cerebellar abscess was entered, and from 10

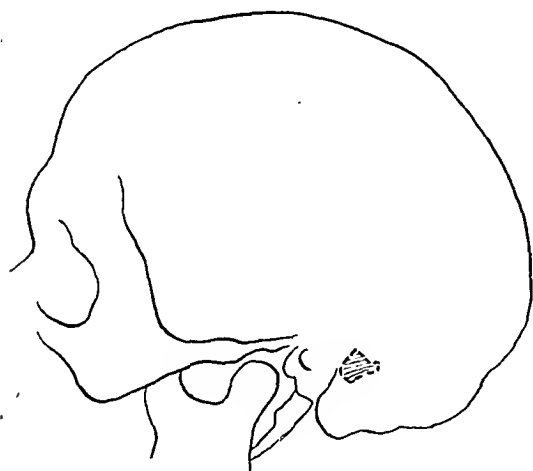


FIG. 10A

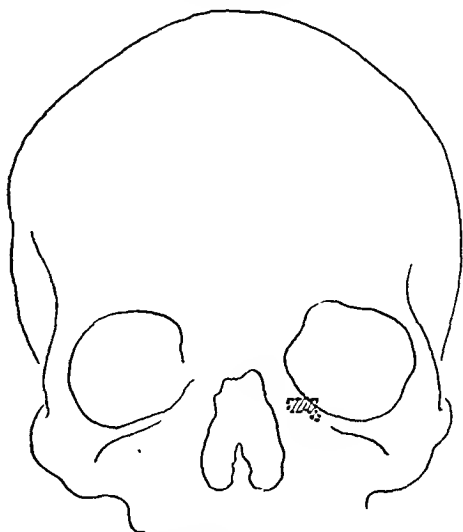


FIG. 10B

FIGS. 10A and B.—Case 8: Tracing of lateral and anteroposterior roentgenograms. Note the position of the shell fragment in the posterior fossa.

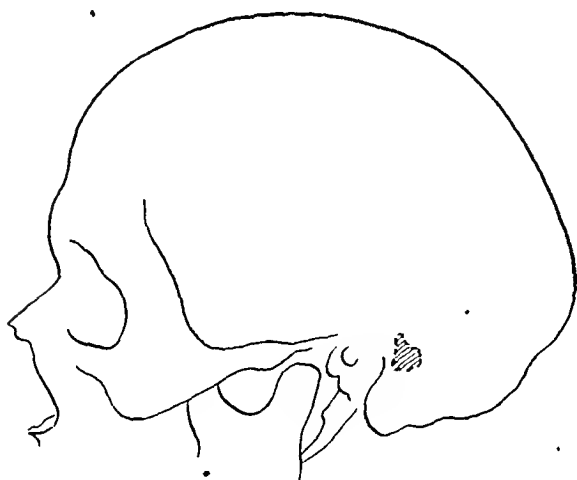


FIG. 11A

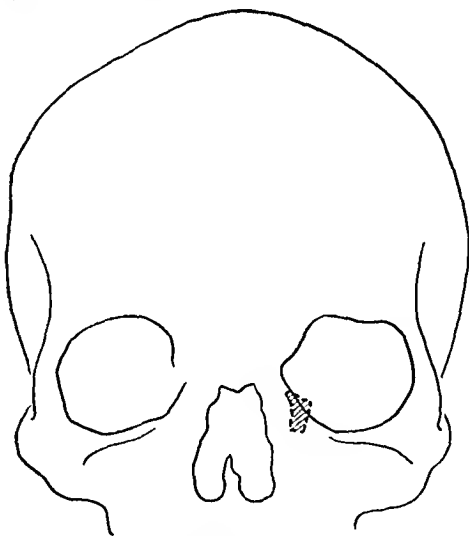


FIG. 11B

FIGS. 11A and B.—Case 8: Tracing of lateral and anteroposterior roentgenograms showing rotation of shell fragment in the cerebellar abscess.

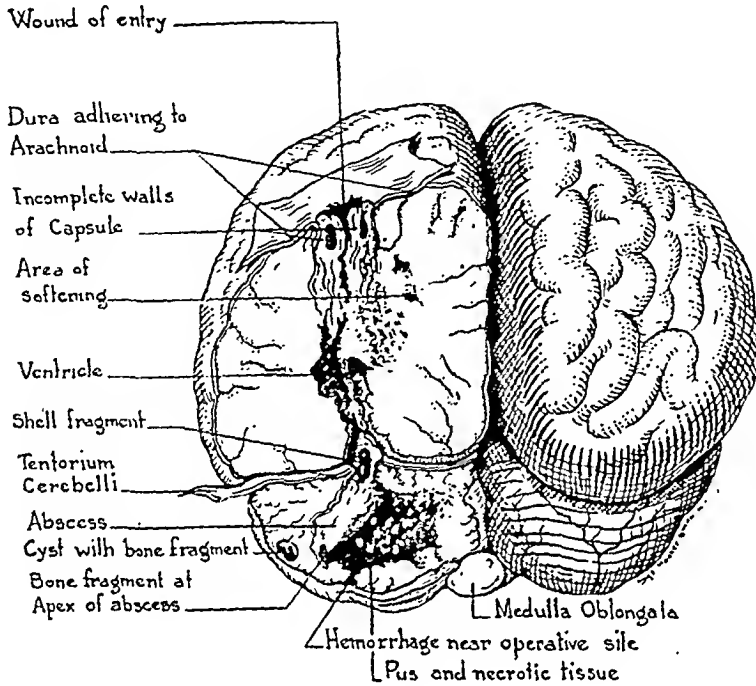
to 15 cc. of pus and some necrotic tissue were removed. Another attempt to grasp the elusive shell fragment failed—as did a magnet, then employed. He died on November 24, 1943, 42 days after injury.

Postmortem examination revealed a hole in the tentorium which opened directly into the large abscess cavity in the left cerebellar hemisphere (Fig. 12). The larger shell fragment was found at this point. Encapsulation of the abscess was, as may be seen in the drawing, very incomplete. The walls were shaggy with necrotic tissue. Near the bur-hole was some recent hemorrhage. One tiny bone fragment was found in the abscess wall, while a second was nicely encapsulated just beyond. The occipital lobe abscess had collapsed, and was healing. Long strands of fibrous tissue entwined about

## COMPOUND, COMMINUTED SKULL FRACTURES

the tract of the missile from the dural opening to the tentorium. An area of softening lay medially. The second small metallic foreign body was found well encapsulated. The occipital horn of the ventricle was intact. Meningitis had not developed.

COMMENT.—Had the occipital lobe wound been débrided early, infection there might well have been avoided. Whether or not the cerebellar abscess would have then developed is problematical, since the metallic foreign body



SCHEMATIC DRAWING SHOWING ENTRANCE AND TRACK OF SHELL FRAGMENT

FIG. 12.—Case 8: Combined occipital lobe and cerebellar abscesses, the former healing following evacuation. Metallic foreign body and a small bone fragment lie free in cerebellar abscess. Encapsulation is incomplete in the cerebellum.

might have been responsible. Débridement of the cerebellar wound through the occipital defect seemed hardly feasible. Indeed, this procedure would not ordinarily have been called for since in but three instances was a metallic foreign body found within an abscess; in all others they were clearly sealed-off in their own scar tissue capsules. Doubtless some will later give trouble, but if at this time one attempted to remove all metallic foreign bodies in the brain, much more harm than good would be done. In retrospect, it would appear that our vain efforts to remove this relatively inaccessible shell fragment negated the benefits of evacuating the abscess. Perhaps, had penicillin been available, its use, both locally and generally, might have saved the day. At least, drainage failed to do so!

*Treatment of Wound Infection Complicated by Cerebral Fungus.*—This was varied according to whether the latter was associated with relatively localized encephalitis, or with, in addition, an abscess. Five of the ten cases in this series fell into the former category. In each the fungus grew slowly. In only two did it become large, fungating, and require excision. The other three regressed spontaneously, without any special treatment other than

general sulfonamide therapy. A sixth patient developed meningitis, but recovered under drug therapy alone. (The causative organism could not be identified in this case, since at that time the laboratory had not begun to function.) A seventh patient with a huge left frontal fungus, extruded a deep abscess, capsule and all, as it was being débrided, and thereafter made an uneventful recovery. The infection in this instance was mixed, both *aerobic hemolytic Streptococcus* and *aerobic hemolytic Staphylococcus albus* having been identified. The three patients who succumbed were admitted during the Salerno fighting, with far advanced infections. In two, the fungus involved the left frontal lobe, while the left parietal lobe was affected in the third. Each was associated with an abscess which was either not found or if so, evacuated too late. Meningitis followed intraventricular rupture of the abscess in two instances, while in the third the ventricle ruptured externally through the extruding fungus.

*Dispositions.*—Of the 95 surviving patients, 23 were returned to duty in this theater, while the remainder, 72, were evacuated to the Zone of the Interior for further treatment and disposition. The principal factors causing this latter classification were: the cranial defect, the neurologic changes and the associated injuries (see Table V). More than one of these factors were frequently responsible. Reclassification was necessary in 38 patients because of the skull defects alone. It is quite likely that the number eventually returned to duty will be appreciably greater after cranioplasty and recovery from certain of associated injuries. Actually, if appropriate materials were at hand, many skull defects which necessitated reclassification could have been repaired here.

#### SUGGESTIONS FOR THE EARLY MANAGEMENT OF HEAD INJURIES

As soon as practicable after wounding the scalp should be shaved for at least three inches about the wound, and washed with soap and water. Sulfonilamide crystals may be lightly sprinkled on, and an ample dressing securely applied. Blood loss, shock, and associated injuries require treatment priority according to their severity. Head injuries usually travel well preoperatively, although this is not invariably the case. The patient should be evacuated as directly as possible to a hospital in which deliberate neurosurgery can be performed. The care with which initial débridement is done has much to do with the eventual outcome. Should either surgeon or proper facilities be lacking, further evacuation is preferable to poor débridement.

#### SUMMARY AND CONCLUSIONS

One hundred cases of compound, comminuted fractures of the skull produced by missiles have been analyzed. More wounds were caused by shell fragments than by all other means. Inner table fractures were sometimes overlooked and occasionally led to serious complications. Tripod incisions often gave trouble; it is recommended that they be avoided when possible. Convulsions were uncommon in the first few weeks; their occurrence was sometimes an early manifestation of abscess formation. Subdural hematoma was present in but two cases. Nineteen patients developed super-

## COMPOUND, COMMINUTED SKULL FRACTURES

ficial wound infections of varying degrees, while in 22 the infections were deep-seated. These were manifested by abscess, meningitis, cerebral fungus or some combination thereof. There were five deaths, all of which occurred in the latter group.

TABLE V  
DISPOSITIONS

To: Class A. (full duty).....	3
Class B. (limited duty).....	20
Class C. (returned to the Zone of the Interior for further treatment and disposition).....	72
Died.....	5
<hr/>	<hr/>
Total.....	100
Classified C, because of skull defect alone.....	19
Classified B, because of skull defect alone.....	19
<hr/>	<hr/>
Total reclassification due to skull defect alone.....	38
Total number in which skull defect was a factor.....	81
Total number in which neural damage was a factor.....	38
Total number in which associated injuries were factors.....	23

Incomplete débridement was the largest single factor contributing to wound infection. In those cases in which all bone fragments had been removed, infection was uncommon and seldom deep, whereas, if débridement had been incomplete or not performed at all, infection was common and usually deep. Bacteria cultured from these wounds were principally skin inhabitants of low virulence.

Treatment consisted in evacuation of pus and removal of associated bone fragments and/or metallic foreign bodies, as well as of adjacent necrotic tissue and old blood. Abscess capsules were disturbed as little as possible. Sulfonamide therapy was employed as an adjuvant. Failures resulted only in those five cases in which, for one reason or another, this procedure was not carried out.

Experience, judgment, and skill, as well as proper neurosurgical armamentarium are prerequisite to good primary débridement. It is recommended, therefore, that patients with severe head wounds be evacuated as directly as possible to a hospital in which these are available, even though a few additional hours be required.

ADDENDUM: Following submission of this paper in April, 1944, the number of penetrating wounds of the skull treated in the Mediterranean Theater of Operations has increased several fold. Figures based upon 974 cases from the Tunisian, Sicilian, and Italian Campaigns show the incidence of deep infection to have been 12.2 per cent. During the past year in particular, débridements have been carried out with more thoroughness. Penicillin therapy (25,000 units intramuscularly every three hours) has been routine. The rate of deep infection has been further reduced.

## THE SURGICAL MANAGEMENT OF COLON AND RECTAL INJURIES IN THE FORWARD AREAS

MAJOR LAWRENCE E. HURT, M.C., A.U.S.\*

THIRTY-NINE battle casualties sustaining injuries of the colon and rectum were operated upon initially by a general surgical team of an auxiliary surgical group functioning with the Fifth Army in Italy. Surgeons engaged in the initial management of intra-abdominal war injuries, particularly colon injuries, are cognizant of the fact that many patients fail to survive. Ogilvie<sup>1</sup> reported 107 injuries of the colon with 63 deaths. In a previous article, using a larger series of cases operated upon by surgeons of our group, the author<sup>2</sup> attempted an appraisal of numerous factors that exerted considerable influence upon mortality. Some of these factors were time-interval between wounding and operation, concomitant wounds, varying degree of peripheral circulatory collapse, and types of operations performed. During the past two years an intensive and comprehensive effort has been put forth by surgical consultants and surgeons in order that an effective decrease in mortality might be obtained in all war injuries. The purpose of this article is to present a brief description of those methods of management employed in a theater of war, and their application to the initial surgery of 39 injuries of the colon and rectum.

Colonel Edward D. Churchill,<sup>3</sup> Theater Consultant in Surgery, has suggested that the surgical care of a severely wounded soldier be divided into three phases—initial, reparative, and reconstructive.

For clarity, it is well to explain that the initial surgery of these colon and rectal injuries was performed in Field Hospitals. The "first-priority" surgical hospital (a platoon of a Field Hospital) is located in physical conjunction with the Division Clearing Station at the rear of the Division boundary. A platoon of a Field Hospital is a small mobile hospital under tentage, having a bed capacity of 30, which can be increased rapidly to 50, or more. It is divided into four sections—resuscitation, X-ray and small laboratory, surgery and surgical supply, and postoperative. When functioning under average conditions, each section can be adequately housed in a ward tent. Essential items of equipment necessary for the performance of major surgical procedures are provided. Administrative and departmental duties commensurate with the successful operation of a hospital are performed by the assigned personnel of the platoon. All professional duties, that is, resuscitation, surgery, and postoperative direction are performed by attached personnel. The attached personnel are members of general surgical and shock teams of an auxiliary surgical group—usually four or more teams depending on the demand and the tactical situation. A general surgical team consists of three medical officers—a general surgeon, an assistant surgeon, and an anesthetist, a surgical nurse and two enlisted men trained as surgical technicians.

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\* Surgeon, General Surgical Team, 2nd Auxiliary Surgical Group.

## INJURIES OF COLON AND RECTUM

Patients not considered "first-priority" are transported from the clearing company to the evacuation hospital usually located five to 15 miles to the rear. The reparative phase of surgery is ordinarily a function of fixed hospitals located in the zones of communication. Those patients requiring reconstructive surgery over a prolonged period of time are evacuated to the Zone of the Interior (Z. I.) that is, the United States or the United Kingdom.

All of the patients underwent initial surgery during the Italian Campaign between the dates of October 1, 1943, and October 15, 1944. This series represents 39 unselected and consecutive hospital admissions sustaining colon and rectal injuries seen by a general surgical team of an auxiliary surgical group. All patients irrespective of multiplicity and severity of wounds, long time-interval, or severe peripheral circulatory collapse were given the benefit of surgery after maximal resuscitation. Most of the casualties were American soldiers. The remainder were British, French Colonials, and German prisoners of war. The youngest patient was 18 years of age, while the oldest was 38. The average age was 25 years.

Before proceeding further, the author wishes to offer an explanation for any statements that might be interpreted as original or positive. In the absence of complete works of reference, many statements are based upon the experience of surgical consultants and surgeons participating in this work.

### WOUNDING AGENTS AND TIME-INTERVAL

Most enemy weapons encountered by soldiers of this theater employ the high explosive principle of fragmentation. The fragment wounds were caused by either artillery and mortar shells, grenades, antipersonnel bombs or mines. These agents frequently produced multiple severe wounds. Some of the concomitant wounds were intrapleural injury, traumatic extremity amputation, and compound comminuted fractures of the skull, long bones, and pelvis. Early, many of these concomitant wounds were complicated by hemorrhagic and traumatic shock, and, in some instances, followed by a long period of sepsis. Wounds caused by rifle, machine gun and machine pistol fire are usually single, and occurred in the ratio of approximately one to three, as compared to fragments (Table I).

TABLE I  
WOUNDING AGENTS

Agents	No. of Cases	Per Cent
Fragment.....	30	76.9
Bullet.....	9	23.0

The time-interval is the time in hours that elapses between wounding and operation. The shortest time-interval was four hours while the longest was 102 hours. The average time-interval was 15 hours (Table II).

A short time-interval is desirable, particularly in the presence of increasing peritoneal contamination and continuing hemorrhage. In our experience, a

TABLE II

## TIME-INTERVAL—WOUNDING TO OPERATION

Time in Hours	No. of Cases	Died	Per Cent
0-6.....	5	2	40.0
6-12.....	20	5	25.0
12-18.....	6	2	33.3
18-24.....	1	1	100.0
Over 24.....	7	3	42.8

Average time-interval—15 hours.

short time-interval has not contributed materially toward a decreased mortality in intra-abdominal injuries because some of the most severely wounded came to surgery who would have died had the time-interval been longer.

## SHOCK—RESUSCITATION THERAPY—PREOPERATIVE PREPARATION

For the surgeon working in forward hospitals, battle casualties offer inexhaustible opportunities for observing hemorrhagic and traumatic shock, with varying degree of peripheral circulatory failure. For convenience, shock has been arbitrarily classified as suspected, moderate, and severe. This classification was prepared from recorded blood pressure, pulse, color, extensiveness of wounds and condition of the skin. Blood pressure was the most consistent recorded finding. Those patients with a systolic pressure of 100 mm. Hg. plus were put in the suspected group. In our experience, this group of patients developed varying degree of peripheral circulatory failure during surgery whenever preoperative resuscitation was omitted. Those exhibiting a systolic pressure between 80 and 100 mm. Hg. were put in the moderate group and those between 0 and 80 mm. Hg. in the severe group. Certainly, errors in classification have occurred, particularly in the suspected and moderate groups. For example, a patient might have been admitted in incipient hemorrhagic and traumatic shock with a systolic pressure in excess of 100 mm. Hg. and yet he was put in the suspected group. Of 39 patients, 12 arrived at the hospital in suspected hemorrhagic and traumatic shock (Table III). Two of the 12 patients died; one of bilateral lobar pneumonia on the seventh postoperative day and the other of peritonitis on the tenth postoperative day. Ten of the 39 patients fell into the severe group. Eight of the ten patients failed to survive the initial phase of surgery in spite of vigorous replacement therapy.

TABLE III

DEGREE OF SHOCK IN RELATION TO TIME ELAPSED BETWEEN WOUNDING AND HOSPITAL  
ADMISSIONS—DEATHS

Degree of Shock	Hours					Total Cases	Died
	0-6	6-12	12-18	18-24	Over 24		
Suspected.....	1	8	1	—	2	12	2
Moderate.....	3	9	2	—	3	17	3
Severe.....	1	3	3	1	2	10	8

The majority of patients in severe shock responded within a three-hour period to 2,000 cc. of whole blood, as indicated by a restored systolic blood

## INJURIES OF COLON AND RECTUM

pressure of or above 100 mm. Hg. Those patients whose response was slow, or *nil*, received 2,500 to 4,500 cc. of blood within three hours. Five of the eight patients died within the 24th postoperative hour of peripheral circulatory collapse. This observation only confirms the substantiated fact that simple restoration of effective blood circulatory volume does not necessarily alleviate peripheral circulatory collapse. Three patients died after the 24th postoperative hour. Sepsis was the dominant cause of death in this group.

Most plasma was administered before the patient arrived at the hospital. Whenever possible, blood was used to elevate the lowered circulatory volume (Table IV). The total volume of blood administered was approximately three times that of plasma.

TABLE IV

### UNITS OF PLASMA AND BLOOD USED IN RESUSCITATION

Agent	Rgt. Colon	Transverse	Left	Rectum	Total Cases	Total Units	Average
Plasma.....	27	7	31	9	30	74	2.4
Blood.....	45	13	57	14	37	129	3.4

One unit of plasma is equivalent to 250 cc.

One unit of blood is equivalent to 500 cc.

Maximum units of plasma to one patient were six.

Maximum units of blood to one patient were nine.

Immediately after admission to the hospital, the patients were examined by the resuscitation officer and, as soon as possible, by the surgeon and assistant surgeon. The patients admitted in severe shock were given low titer "o" blood rapidly until cross-matching was completed, and oxygen by mask. As soon as the patients exhibited a favorable response to resuscitation therapy, other preoperative measures were instituted. These measures consisted of nasogastric intubation, urinary bladder catheterization for possible genito-urinary tract damage, and skin preparation. Nasogastric intubation is most important since aspiration of vomitus into the respiratory tract during anesthesia might suddenly, or eventually, become disastrous. It has been our policy to pass the Levine tube into the stomach, and, if the gastric contents was free of macroscopic blood, moderate gastric lavage was performed before the induction of anesthesia.

### INJURIES OF THE COLON AND RECTUM

All injuries of the colon included in this series resulted in fecal peritoneal contamination of varying degree. Intraperitoneal injuries of the rectum were placed in the colon group. All of the injuries in the rectal group were extraperitoneal.

\* The types of colon injuries were single or multiple mesenteric, lateral, and antimesenteric perforations; hemisection; transection; and longitudinal tears. Contusions, lacerations not involving the mucosa, injuries to the mesocolon interfering with blood supply, and posterior wall perforations without peritoneal soiling were not included.

Table V is included to emphasize a moderately high incidence of injury to certain related viscera. Some of the factors that determined the likelihood



of injury to related viscera were: Location of the wound of entry; size, contour, and velocity of the missile; and the surface area of the related viscus. The influence of a vast surface area was corroborated by the fact that 13 of the 39 patients sustained injury to the small bowel.

TABLE V

	No. of Cases	INCIDENCE OF INJURY TO RELATED VISCERA								2nd Part of Duodenum
		Small Bowel	Liver	Diaph.	Stomach	L. Kid.	R. Kid.	Spleen	Bladder	
R. C.....	14	3	1	1	—	—	1	—	—	2
T. C.....	4	1	1	3	3	—	—	1	—	—
L. C.....	15	8	2	1	—	2	—	1	—	—
Rectum.....	6	1	—	—	—	—	—	—	3	—

Five of the 33 colon injuries were complicated by injury to the diaphragm: that is, they were thoraco-abdominal wounds. The second part of the duodenum was involved in two of four cases with injuries of the hepatic flexure. Such a high incidence necessitates exposure of this part of the duodenum whenever the hepatic flexure is injured.

#### ANESTHESIA

Ether, open-drop or in a closed system, was used for all operations. Among the anesthetic agents used for induction, excluding ether, were nitrous oxide-oxygen and ethyl chloride. Nitrous oxide-oxygen-ether, using the closed absorption, endotracheal technic was the most frequently used anesthesia. Endotracheal anesthesia was employed in all thoraco-abdominal and separate intrapleural injuries.

#### TYPES OF OPERATIONS PERFORMED UPON THE COLON AND RECTUM

For obvious reasons, primary suture of the unprepared colon in the presence of peritoneal contamination has always been condemned in this theater. Consequently, all initial operations were designed to divert the fecal current outside the peritoneum. The only exception to this rule has been in those patients sustaining injury between the sigmoid and the extraperitoneal rectum. These perforations were closed by suture and supplemented by proximal colostomy (Table VI). The type and severity of the injury occurring between the terminal ileum and sigmoid colon usually determined whether a loop or double-barrel colostomy with spur was to be performed. Single or closely associated multiple anterior and lateral wall perforations and antimesenteric hemisections were exteriorized as loop colostomies. Mesenteric hemisections, transections, and extensive injuries necessitating resection of the colon were exteriorized as double-barrel with spur colostomies. We have endeavored to perform an initial operation that not only diverts the fecal current extraperitoneally, but also leaves the patient with a simple stoma which can be closed secondarily without entering the peritoneal cavity. Since the extraperitoneal closure of a loop colostomy of the right colon is impractical, a single perforation of the right colon was treated by tube colostomy or cecostomy. The tube and about two centimeters of adjacent tissue around the tube were extraperitonealized through a stab

## INJURIES OF COLON AND RECTUM

incision to prevent any subsequent leakage into the peritoneal cavity. At secondary operation, this extraperitonealized portion of colon could be utilized to close the colonic fistula without entering the peritoneal cavity. Three patients were treated successfully by this procedure. .

TABLE VI  
TYPES OF OPERATIONS PERFORMED ON THE COLON AND RECTUM

Type of Operation Performed	Right Colon	Left Colon	Trans. Colon	Rectum	Total	Deaths	
						Number	Per Cent
1. Exteriorization.....	4	12	4	—	20	10	50.0
2. Resection of terminal ileum, cecum, ascending colon and double-barrel ileo- transverse colostomy.....	4	—	—	—	4	1	25.0
3. Tube cecostomy or colostomy.....	3	—	—	—	3	0	—
4. Resection and exteriorization.....	—	1	—	—	1	0	—
5. Suture of perforation and proximal cecos- tomy or colostomy.....	1	2	—	—	3	0	—
6. Proximal colostomy and coccygectomy..	—	—	—	6	6	0	—
7. None (died during surgery).....	2	—	—	—	2	2	100.0

Injuries of the splenic flexure and left half of the transverse colon complicated by those of the left diaphragm and left lung caused by a single missile were operated upon transdiaphragmatically. Some of the advantages of a thoracic operative approach in left-sided thoraco-abdominal wounds were: Excellent visualization of the wound tract; easy removal of the frequently fragmented spleen; mobilization of the splenic flexure under direct vision; and the elimination of the separate celiotomy incision, with its subsequent pain, which permitted the institution of an intensive cough routine so necessary for the postoperative intrapleural injury. Before closure of the diaphragm, the injured segment of the splenic flexure or transverse colon was exteriorized either as a loop or double-barrel colostomy with spur through a stab incision in the left upper quadrant of the abdomen. Likewise, if drainage of the abdomen was desired, the drains were brought out through another, but smaller, stab incision of the left abdominal wall. On the contrary, injury of the hepatic flexure complicated by those of the liver, right diaphragm and right lung caused by a single missile necessitated thoracotomy and a separate celiotomy incision, as the liver offers complete obstruction to exploration of the right abdomen.

The initial surgery of extraperitoneal perforations of the rectum consisted of thorough débridement of the wound tract, suture of perforations, and sigmoid colostomy. In addition, resection of the coccyx and incision of the fascia propria were done to insure adequate drainage of the retroperitoneal, posterior, and pararectal spaces. All sigmoid colostomies were of the loop type. However, a recent personal communication with surgeons in Base Hospitals has revealed that loop colostomy for rectal injuries has failed, in many instances, to completely divert the fecal current. Consequently, patients with rectal injuries have arrived at the Base from the Forward Area Hospitals with fecally contaminated buttock wounds, and the rectum filled with feces. In the future, we expect to transect the sigmoid and prepare a spur at the

time of initial operation of all extraperitoneal rectal injuries. Colcock<sup>4</sup> has reported from a hospital in the Zone of Communication that osteomyelitis of the sacrum has been a frequent complication of coccygectomy in those with rectal wounds. Because of this, posterior drainage is now being accomplished without resection of the coccyx. It is the feeling of most of our surgeons that adequate drainage can be ensured through a curved incision inferior to the coccyx; incision of the fascia propria; and opening of the posterior and pararectal spaces by blunt dissection.

#### USE OF SULFONAMIDES AND PENICILLIN—POSTOPERATIVE CARE

The methods of administration and dosage of sulfonamides, according to a suggested regimen developed by Theater and Army Consultants for the guidance of Forward Area surgeons, were constant throughout the entire series of cases. An amount not exceeding 10 Gm. of sulfanilamide per patient was used at operation. Five grams were dusted into the peritoneal cavity before closure of the abdominal wall. The remaining 5 Gm. were dusted into, and distributed proportionately, among the operative sites of concomitant wounds. Consequently, those patients sustaining only an intra-abdominal injury received 5 Gm. of sulfanilamide at operation. Intravenous sodium sulfadiazine was started 24 hours after operation in the dosage of 2.5 Gm. every 12 hours until the patient could tolerate 1 Gm. orally every four hours. Therapy was continued from five to seven days and longer, if indicated. The only exceptions to this rule were two patients whose urinary output did not exceed 1,200 cc. daily, in spite of an adequate fluid intake.

Penicillin for routine use in intra-abdominal injuries was available for only the last ten of the 39 patients. Twenty-five thousand units of penicillin in 10 cc. of distilled water were injected into the peritoneal cavity in conjunction with 5 Gm. of sulfanilamide before closure of the abdominal wall. Postoperatively, 25,000 units of penicillin were administered intramuscularly every three hours for five days, and longer, if indicated. Five of the ten patients died—four of sepsis and one of anuria. Therefore, in this small series of cases, there was no evident reduction in mortality as compared to that when sulfonamides were used alone.

Postoperative care consisted of skilled nursing, correction of protein and vitamin depletion, and the utilization of specific measures to combat shock and infection. A lowered protein intake combined with the additional loss from hemorrhage, and a lowered vitamin intake were responsible for protein and vitamin depletion. Plasma and blood were administered to elevate the blood proteins and the lowered circulatory blood volume. To insure an effective vitamin "C" level, ascorbic acid was given intravenously until polyvitamins could be tolerated orally. Hydration and nutrition were maintained by the daily administration of 3,000 cc. or more of 5 per cent glucose in normal saline. Ileus and abdominal distention were controlled by nasogastric suction. In the absence of marked peritoneal infection, delayed colostomy function was initiated by the installation of 30 cc. of mineral oil

into the proximal loop of the colostomy on the fourth or fifth postoperative day.

### COMPLICATIONS

Shock and infection were the dominant complications. Most patients admitted in suspected, or a moderate degree of shock, responded favorably to blood and plasma replacement therapy during resuscitation, operation and the postoperative period.

Peritoneal contamination and early infection responded gratifyingly to forward surgery and its adjuncts, sulfonamides and penicillin, for only 12 of the 33 intra-abdominal injuries exhibited objective signs of peritonitis. We have attributed our low incidence of pulmonary complications to routine postoperative bronchoscopy and catheter suction of the trachea of all intra-abdominally injured patients sustaining concomitant intrapleural injury or possessing excessive tracheobronchial secretion. Five of the 33 intra-abdominal injuries developed severe infection of the celiotomy incision, although colostomies were placed in separate incisions. None of the wound infections led to dehiscence. Other complications recorded during the postoperative period are listed in Table VII.

TABLE VII  
COMPLICATIONS

Complications	No. of Cases	Died
Peritonitis.....	12	2
Pneumonia.....	5	2
Atelctasis.....	2	0
Shock (severe).....	8	5
Severe infection of celiotomy incision.....	5	0
Anuria.....	2	2
Shock and peritonitis.....	2	2

### MORTALITY

Thirteen of the 39 patients died—a mortality rate of 33.3 per cent (Table VIII). Injury to the colon or rectum alone occurred in eight of the 39 cases. Five of the eight patients sustained injuries of either the right,

TABLE VIII  
MORTALITY

	No. of Deaths	Per Cent
Right colon.....	6	42.8
Transverse colon.....	2	50.0
Left colon.....	5	33.3
Rectum (extraperitoneal).....	0	—
Total deaths.....13	Mortality rate.....33.3%	

transverse, or left colon, and three of the extraperitoneal rectum. All of these patients survived, and were evacuated to the Zone of the Interior on an average of 65 days after initial surgery. The remaining 31 cases were complicated by concomitant wounds varying in severity from mild soft-tissue wounds to such severe injuries as small bowel transections, necessitating two small bowel resections; kidney fragmentation; liver perforation, compound

comminuted fractures of the skull, pelvis and long bones; intrapleural injury; and traumatic extremity amputation.

Two patients died during surgery. Both were admitted to the hospital with a long time-interval; septic from a generalized peritonitis; and in severe peripheral circulatory collapse. Both responded very poorly to resuscitation therapy. In our experience, all battle casualties presenting a picture of sepsis and profound peripheral circulatory collapse tolerate anesthesia and surgery very poorly, and are obviously designated "bad risks."

Two deaths on the eighth postoperative day were attributed to uremia. Both presented evidence of urinary suppression at the end of the first postoperative day, which gradually increased until death. They were admitted to the hospital in severe peripheral circulatory collapse and given either low titer "o" or cross-matched blood during resuscitation and surgery.

Bilateral lobar pneumonia was responsible for two deaths. Their injuries were of the thoraco-abdominal type, with the pneumonic process involving first the injured lobes and, later, the lobes of the contralateral lung.

Five of the 13 deaths occurred during the first postoperative day. All failed to respond to quantities of blood up to 4,500 cc. administered during the resuscitation, operative, and postoperative periods. The 12th and 13th deaths were due to generalized peritonitis. One of these died on the ninth postoperative day, and the other on the 12th postoperative day.

Detailed information concerning the reparative phase of surgery of the 26 surviving patients was obtained by communication with the office of the Base surgeon and surgeons of Station and General Hospitals located in the Zones of Communications. All of the patients were evacuated to the Zone of the Interior on an average of 65 days following initial surgery.

We have not obtained any information concerning the patients after their arrival in the Zone of the Interior.

#### SUMMARY

Initial surgery of 39 injuries of the colon and rectum was performed by a general surgical team of an auxiliary surgical group functioning with the Fifth Army in Italy. Most of the injuries were caused by fragments. Twenty-nine patients were operated upon within 12 hours of injury; five within six hours. A short time-interval can contribute toward an increased mortality, because more of the severely wounded come to surgery. The average time-interval was 15 hours. The contribution of shock toward an increased mortality was exemplified by five deaths, in spite of vigorous replacement therapy, out of eight patients admitted in severe shock. The second part of the duodenum was injured in two of four injuries of the hepatic flexure. Peritoneal contamination and early infection responded gratifyingly to Forward surgery and its adjuncts, sulfonamides and penicillin, for only 12 patients exhibited objective signs of peritonitis. Eight patients sustaining injuries of the colon or rectum alone were treated successfully. Thirteen colon injuries complicated by severe concomitant wounds died—a

mortality rate of 33.3 per cent. Severe shock, secondary to injuries of the colon complicated by concomitant wounds, was the dominant cause of death. Next to shock, sepsis was the leading cause of death.

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# THE MANAGEMENT OF WAR INJURIES OF THE EXTRAPERITONEAL RECTUM

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INJURIES OF THE RECTUM present many problems which are peculiar to it alone. These problems arise largely from its physiologic and anatomic properties. As the organ of temporary storage and evacuation of the solid wastes of the intestinal tract, its contents teem with organisms, many of them potential pathogens, both aerobic and anaerobic. Anatomically, it is for the most part unprotected by infection-resisting peritoneum. It traverses a tissue which is highly vulnerable to infection, and it is difficult of surgical access. In order to understand more fully the implications of the anatomic problems, let us examine some of the essential details of the relationships of the rectum.

The rectum, the terminus of the large bowel, is arbitrarily said to begin at the level of the third sacral vertebra and end in the anal canal (Fig. 1). Its average length is 12 cm. The lateral and anterior surfaces of the proximal portion, 5 cm. in the male, 7 cm. in the female, are invested with peritoneum. The posterior surface of this proximal portion is retroperitoneal, the distal portion is infraperitoneal. The rectum ending below at the level of the internal sphincter to become the anal canal, is approximately 2 cm. long and is circumvested by the external sphincter. The internal structure of the pelvic floor, through which the rectum passes, may be likened to a trough, the sides of which are formed by the levators ani and coccygei, flat, sling-like muscles originating from the internal surfaces of the pelvis on either side, from the pubic tubercle in front to the coccyx behind, to join in a median raphe below. The triangular anterior wall is formed by the urogenital triangle, while the triangular posterior wall is formed by the sacrum and coccyx. Through this trough-like space descend the rectum posteriorly and the urogenital tract anteriorly. Over this trough-like space and its viscera, the peritoneum is loosely draped as a cover. Actually, this space is more potential than real, since it is filled with a cellular areolar tissue. This space is, therefore, bounded laterally by the levators, inferiorly by their raphe, anteriorly by the urogenital triangle, posteriorly by the sacrum and coccyx and superiorly by the peritoneum, and will be referred to as the infraperitoneal space. When this space is distended by pus or blood, its expansion is found to be definitely limited in certain directions, relatively unlimited in others. Rigid fascial planes prevent extension in any direction except superiorly. Laterally, these fascial planes are formed by the medial investment of the levators, the superior levator fasciae. These layers join inferiorly over the raphe, and become continuous at the rectal and urogenital outlet with a similar layer of fascia loosely investing these viscera, the endopelvic fascia. Anteriorly, the superior levator fascia

## INJURIES OF EXTRAPERITONEAL RECTUM

fuses with the deep layers of the urogenital triangle, and posteriorly, with the periosteal layer of the sacrococcygeal fascia. Expansion of the infraperitoneal space is, therefore, limited inferiorly, laterally, anteriorly and posteriorly by fascial planes, but is relatively uninhibited superiorly by the loose peritoneal roof. Even this, however, is rather firmly adherent laterally along the line of origin of the levators, at the so-called "white line" where levator fascia fuses with the obturator fascia above. Since the peritoneum is most loosely attached over the sacral promontory on either side of the rectum, it is

### CORONAL SECTION OF PELVIS

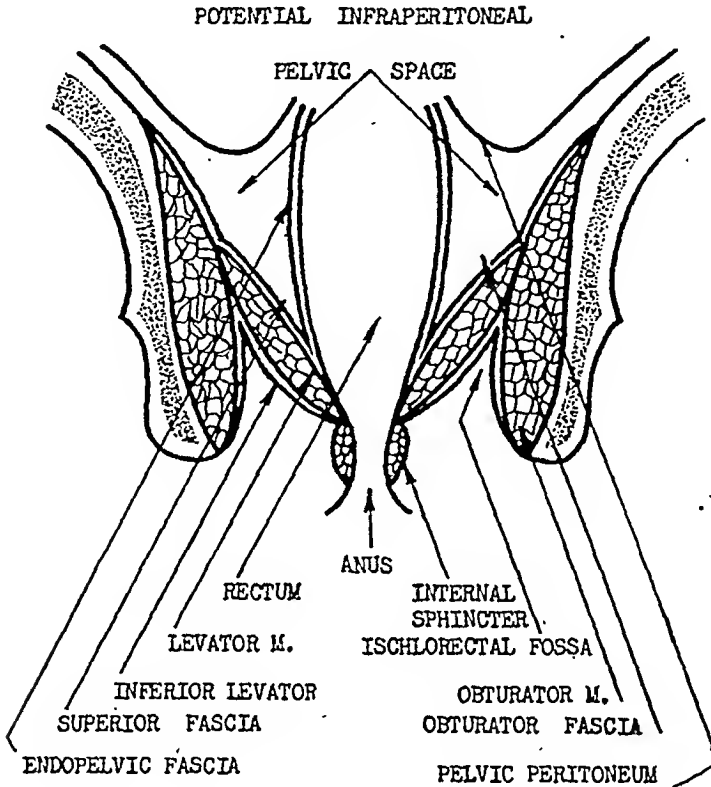


FIG. 1.—Diagram of coronal section of pelvis demonstrating the infraperitoneal space.

here that the infraperitoneal space readily communicates with the retroperitoneal space. When the infraperitoneal space becomes distended with pus or blood, it, therefore, spills through this escape route into the retroperitoneal space. This has been demonstrated experimentally in the cadaver by the serial roentgenologic studies of progressive injection with sodium iodide solution into the infraperitoneal space (Figs. 2 and 3). It is also well illustrated in one of the cases presented below (Case 1).

While perforation of the infraperitoneal portions of the rectum and bladder cause infection of the infraperitoneal and eventually of the retroperitoneal space, perforation of the anal canal causes infection of the ischioanal fossae on either side. These are symmetrical pyramidal spaces, one on each side beneath the pelvic floor. The medial wall of each space is formed above by the levator and its investing fascia, the inferior levator fascia, and below by



the anal canal. The lateral wall of each is formed by obturator internus and its investing fascia, and the base by the superficial fascia and skin alone (Fig. 1). Expansion of these spaces is limited on all sides except at the base, so that the ischiorectal abscess points at the skin. Again, serial roentgenologic studies of progressive injection with sodium iodide solution of the ischiorectal space in the cadaver illustrates the barriers formed by the pelvic floor between these spaces and the infraperitoneal space (Fig. 4). Extension of infection does not occur from one to the other except by trauma to the levator and to investing fasciae.

The clinical syndrome of retroperitoneal sepsis was a nightmare to the surgeons of World War I.<sup>1, 2</sup> Little was written, and apparently little was known, regarding its prophylaxis or treatment. Drummond reviewed the problem at the close of World War I.<sup>3</sup> His mortality statistics are discouraging: "From the table of gunshot wounds of the rectum there were fourteen deaths out of sixteen cases with two recoveries; seven died from shock, six from retroperitoneal sepsis and one from peritonitis with retroperitoneal sepsis." His clinical description of the acute casualty is borrowed from Fraser<sup>4</sup> and is vividly imaginative. "John Fraser also laid great stress on retroperitoneal sepsis, and applied the term 'colon septicaemia' to a group of symptoms present in cases of colon wounds with a spread of infection to the retroperitoneal tissue." Drummond's suggestions as to treatment reveal that the problem at that time was still very much in the experimental stage, although some of his suggestions have proved extremely practical:

"In extraperitoneal wounds of the rectum the only hope of success lies in very free local drainage carried out at the earliest possible moment. With a view to establishing efficient drainage, I removed in two cases, the uninjured coccyx in addition to free drainage of the wounds of entry and exit, and found by stripping up the bowel that one was able to expose the wound in the rectum and was thus enabled to drain and pack off the surrounding parts and prevent further tracking by retroperitoneal hemorrhage."

During the past two years, we have been fortunate enough to administer definitive treatment to a moderate number of patients returning from the battlefields in various stages of convalescence from war wounds of the rectum. In addition, we have been able to evaluate the treatment of many others who have not remained under our care. From these observations, we feel that progress has been made during this war in the management of extraperitoneal injuries of the rectum. We feel that sufficient progress has been made to warrant crystallization of the surgical management. We wish to emphasize here the part played by surgical prophylaxis in contrast to the supportive measures of blood, plasma, and chemotherapeutic agents. Invaluable as they are, when applied alone, without surgery, they may influence the early mortality rate in assisting recovery from shock, but not appreciably the morbidity or late mortality rate from chronic sepsis. These measures have been proved to be merely adjuvants and not in any way substitutes for early and properly executed surgery.

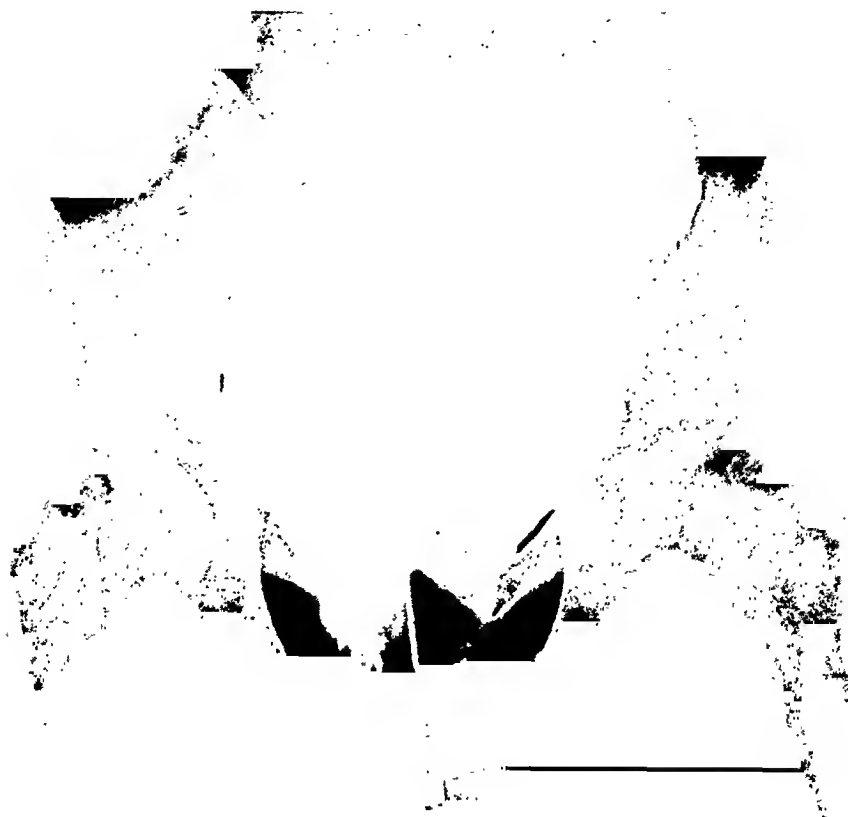


FIG. 2.—Anteroposterior radiograph demonstrating the extension of the infraperitoneal into the retroperitoneal space by injection of sodium iodide solution into the former space in the cadaver.



FIG. 3



FIG. 4

FIG. 3.—Lateral radiograph as in Figure 2.

FIG. 4.—Anteroposterior radiograph demonstrating the confines of the right ischioirectal fossa after injection with sodium iodide solution in the cadaver.

What, then, is properly executed surgery? Examination of the anatomy of the pelvic floor reveals that a very simple approach to the infraperitoneal space lies posteriorly. Through a midline incision, one may easily expose and excise the coccyx, then incise the precoccygeal fascia and thus expose the areolar tissue of the perirectal space. By loosely packing this space one has provided very adequate dependent drainage well calculated to prevent the spread of infection and development of retroperitoneal sepsis. Moreover, the exposure of the posterior and lateral walls of the lower rectum permits exploration for laceration of the viscus, and an opportunity to suture it. Failure to perform the latter procedure may result in chronic sepsis and

retardation of wound healing, and, finally, the establishment of a chronic fistula, even in the presence of a proximal colostomy. However, it is recognized that this ideal may not be attainable at the primary procedure because of the precarious condition of the patient or the pressure of other life-saving measures. Furthermore, even when the patient's condition and other circumstances permit, this ideal may still be unattainable because in many instances the laceration will be inaccessible, in others, it will not be detectable because of hemorrhage in the rectal wall, while in still others, perforation will appear as a result of infarction only several days after trauma.

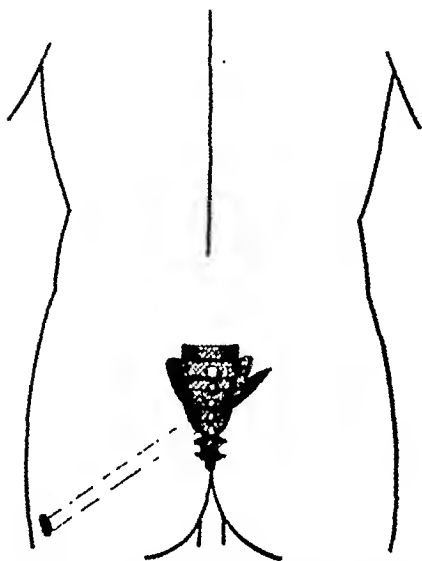


FIG. 5.—Diagram illustrating the course of the bullet. (Posterior view)

We have selected for presentation a number of clinical cases from which we have evolved a rationale of management, and we shall present them below *pari passu* with our observations regarding their contributions to the final plan of management.

#### CASE REPORTS

**Case 1.**—A 23-year-old soldier sustained a penetrating gunshot wound of the left buttock in North Africa on March 27, 1943. The bullet perforated the rectum and lodged in the bodies of the first and second sacral vertebrae (Fig. 5). Celiotomy was performed through a lower left rectus incision the following morning. Apparently, no intraperitoneal lesion was found and the wound was closed without drainage and without colostomy. The celiotomy wound became infected, and was widely opened (Fig. 6). Fecal drainage appeared from the wound of entrance in the left buttock. The patient became acutely ill and rapidly malnourished, despite vigorous supportive measures. When he arrived at the Zone of Interior, April 30, 1943, he was severely septic and emaciated. The celiotomy wound was superficially epithelized, with wide musculofascial defect. There was a deep-lying tender mass in the right lower quadrant against the right inguinal ligament. There was frank fecal drainage from the wound of entrance in the lateral aspect of the left buttock, which communicated with a fecal abscess underlying the gluteal muscles. There was a large decubitus ulcer over the sacral region.

## INJURIES OF EXTRAPERITONEAL RECTUM

On admission, the R. B. C. was 3.29 million per cu. mm., W. B. C., 7,400 cu. mm.; hemoglobin, 12.6 Gm. per cent; uranalysis and Kahn were negative. Roentgenograms revealed a bullet lodged near the right sacro-iliac joint. On May 6, 1943, an attempt was made to improve the drainage of the fecal abscess of the gluteal region. On May 11, 1943, the mass in the right lower quadrant of the abdomen was incised and found to be a fecal abscess. Lipiodol injection of the incision in the right inguinal region revealed a communication with the infraperitoneal space (Figs. 7 and 8). Despite vigorous supportive measures with plasma, blood and sulfonamides, the sepsis and emaciation increased. A barium meal revealed no evidence of an internal fistula involving small bowel or cecum. All the evidence indicated that the fecal abscess in the right inguinal region was an overflow from the infraperitoneal space, which was being filled by an infraperitoneal perforation of the rectum (Fig. 9). Therefore, on June 10, 1943, a sigmoid colostomy was performed to divert the fecal stream. There

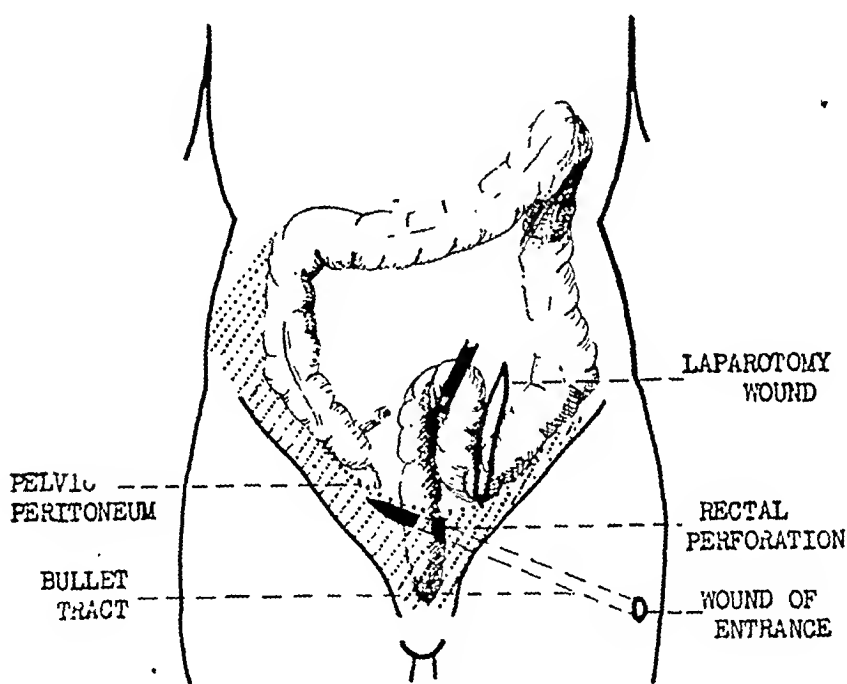


FIG. 6.—Diagram illustrating the infraperitoneal perforation of the rectum and the celiotomy wound. (Anterior view)

was some improvement for a while, but large amounts of malodorous pus continued to discharge from the left buttock and through the right inguinal incision. On August 2, 1943, the discharge from the right inguinal incision again became feculent and it was presumed that an internal fistula had developed with the cecum or ascending colon. Barium studies failed to reveal this internal fistula. On August 9, 1943, the discharge from the right inguinal incision became blood-tinged. The prothrombin time was normal. On August 10, 1943, rather profuse hemorrhage appeared from the right inguinal incision, distal sigmoid colostomy orifice, the rectum and left buttock incisions, and the patient died despite attempts to pack off the vessels through the wound in the right inguinal region, and the use of multiple transfusions.

Autopsy revealed marked emaciation. The peritoneal floor of the pelvic cavity had been raised by the underlying necrotizing infection of the infraperitoneal space. This infection was not only posterior, about the rectum, but had extended anteriorly about the bladder. It communicated with the abscess underlying the left gluteal muscles through the bullet tract in the left levator muscle. There was a perforation of the rectum in its posterior wall about 8 cm. above the anal orifice. The bullet lay embedded in a crumbled mass of cancellous bone of the first and second sacral vertebrae near the sacro-iliac joint just above the peritoneal reflexion. Thence, the fecal abscess had

extended retroperitoneally to the right iliac fossa where it continued to burrow upward along the posterolateral wall of the ascending colon almost to the liver. About midway in the ascending colon, a secondary wide communication had become established with the retroperitoneal space (Fig. 10).

COMMENT: It seems very unlikely that this internal fistula could have been traumatic in origin. In fact, if it had been present prior to establishing the sigmoid colostomy on June 10, 1943, the external fecal fistula in the left gluteal region and the right inguinal region would not have lost their



FIG. 7.—Anteroposterior radiograph after lipiodol injection of right inguinal incision showing upward extension along right iliac fossa and downward to the perirectal space.

fecal characteristics after sigmoid colostomy. It was not until August 2, 1943, that the discharge from these again became feculent and it was then that this secondary communication proximal to the colostomy must have become established. There was a septic erosion of the outer walls of many visceral branches of the pelvic vessels but the exact origin of the hemorrhage could not be located.

This represents a casualty which probably would not have survived more than a few hours were it not for the excellent supportive therapy our soldiers have been receiving at the front—blood, plasma and chemotherapeutic agents. We do not know what the findings were at the time of initial celiotomy except that no intraperitoneal visceral lesion was found. Soon after operation the patient became very ill, and fecal drainage appeared from the wound of entrance. Had a sigmoid colostomy been established at

that time and the infraperitoneal space widely saucerized through coccygectomy, the subsequent course might have been modified. Upon arrival here, the patient was in such poor condition that a major operation did not, at that time, seem feasible. Even diagnostic procedures were exhausting to the patient. From the light of subsequent events, and our observations of similar cases, thereafter, a coccygectomy with widespread saucerization of the infraperitoneal space should have been performed as soon after arrival as possible.



FIG. 8.—Anteroposterior radiograph after barium-filling of rectum showing the extension of barium into the infraperitoneal space and upward toward the right iliac fossa.

together with a sigmoid colostomy. Whether he would have survived such a procedure is problematical, but it would have given him his only chance. Of course, if the internal retroperitoneal fistula into the ascending colon had already been established, even this would have failed, as nothing short of an ileostomy would have diverted the fecal stream, but the evidence indicates that this secondary fistula had not become established until later.

This case, therefore, well illustrates (1) a pathway of spread of infection from the infraperitoneal to the retroperitoneal space. (2) The importance of early surgery for infraperitoneal perforations of the rectum. (3) The futility of supportive treatment in the absence of early surgery. (4) The profound malnutrition resulting from infection of the areolar tissue of the

infra- and retroperitoneal tissues, in the absence of early and adequate drainage.

**Case 2.**—While in action on the Italian front at 1400 hours on April 3, 1944, a 25-year-old soldier sustained multiple shell fragment wounds of the left lower extremity, the right thigh, the left buttock, and the left forearm. The latter caused paralysis of the radial and ulnar nerves and a compound fracture of the radius. At 0230 hours, the following morning operation was performed under open-drop ether anesthesia. All wounds were débrided. Foreign bodies were removed from the left thigh, left buttock, left arm, left foot and right thigh. The left forearm was immobilized in plaster. Through a lower left paramedian incision, the abdomen was explored. A massive extraperitoneal hemorrhage was found in the pelvis. The peritoneum was reflected,

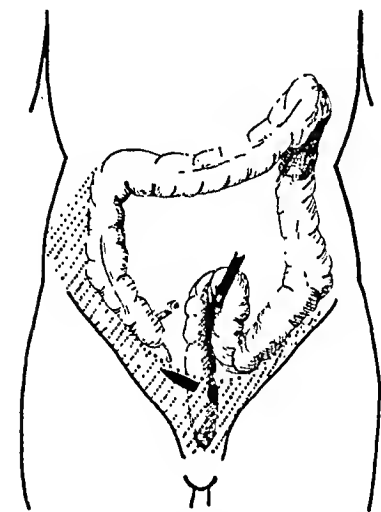


FIG. 9.—Diagram illustrating the extension of the infraperitoneal abscess upward along the right iliac fossa. (Anterior view)

a large shell fragment was removed from the right lateral pelvic wall, and two Penrose drains were inserted extraperitoneally to this site from the lower end of the wound. The surgeon was not cognizant of any rectal perforation at this time and colostomy was not performed. On April 8, 1944, after an enema, feces returned through the wound of the left buttock for the first time, indicating to the surgeon that a contused area in the rectum had sloughed away. A sigmoid colostomy, through a left gridiron incision, was performed without delay, and opened on April 13, 1944. The patient continued to be moderately ill and, April 23, 1944, a left para-anal incision was made through the ischio-rectal fossa into the infraperitoneal space, and the sigmoid colostomy completely divided. On May 15, 1944, examination revealed that the lower 6 cm. of the midline celiotomy wound were unhealed and draining pus. Rectal examination revealed a perforation, 3.5 cm. in diameter, in the posterior wall of the rectum, 5 cm. above the anus, communicating with a large perirectal abscess (Fig. 11). It was draining inadequately through a left para-anal incision, so this incision was enlarged. The granulating wounds of the left lower extremity and right thigh were excised and sutured. The patient had had a nonspecific epididymitis which was gradually subsiding. He was evacuated to the Zone of Interior on July 3, 1944.

On arrival here, the R. B. C. was 4.7 million per cu. mm.; W. B. C., 6,600 per cu. mm.; hemoglobin, 15 mg. per cent. Urinalysis was negative. Serum protein was 5.7 Gm. per cent. N. P. N., 26 mg. per cent. Despite continued supportive treatment of high caloric diet, vitamins, administration of blood and plasma and later penicillin, the clinical picture remained one of chronic sepsis and its attendant malnutrition. Lipiodol injection of the orifice at the lower end of the celiotomy wound revealed a fistula extending laterally along the right wall of the pelvis, puddling about the lower end of the rectum and finally into the rectum and also out through the left para-anal incision (Fig. 12).

On September 25, 1944, through a midline coccygeal incision the coccyx was resected. On incising the precoccygeal fascia a large perirectal abscess was encountered filled with necrotic and suppurative débris. A large perforation, 3 cm. in diameter, was found in the posterior wall of the rectum. The abscess extended anteriorly on both sides of the rectum, on the right further than could be reached by the finger. The perforation of the rectum was sutured, a cigarette drain placed into each anterior

extension of the infraperitoneal space and the cavity loosely packed. Postoperatively, parenteral penicillin 200,000 units daily was administered.

The patient improved to some extent following this procedure. The suture line closing the perforation of the rectum was soon digested in the infectious process. The cigarette drains in the anterolateral extensions were removed in eight days. The left anterolateral extensions closed completely. The right, which was larger, and was suspected of communication with the caudal end of the abdominal wound by way of the lateral wall of the pelvis, seemed at first to be closing but soon began to drain large quantities of pus. The patient began to complain of pressure pain deep in the perineum. On October 31, 1944, a catheter was introduced into this extension and it was filled with lipiodol and roentgenograms taken (Fig. 13). These films revealed a wide sinus extending along the right anterolateral wall of the pelvis almost to the symphysis pubis.

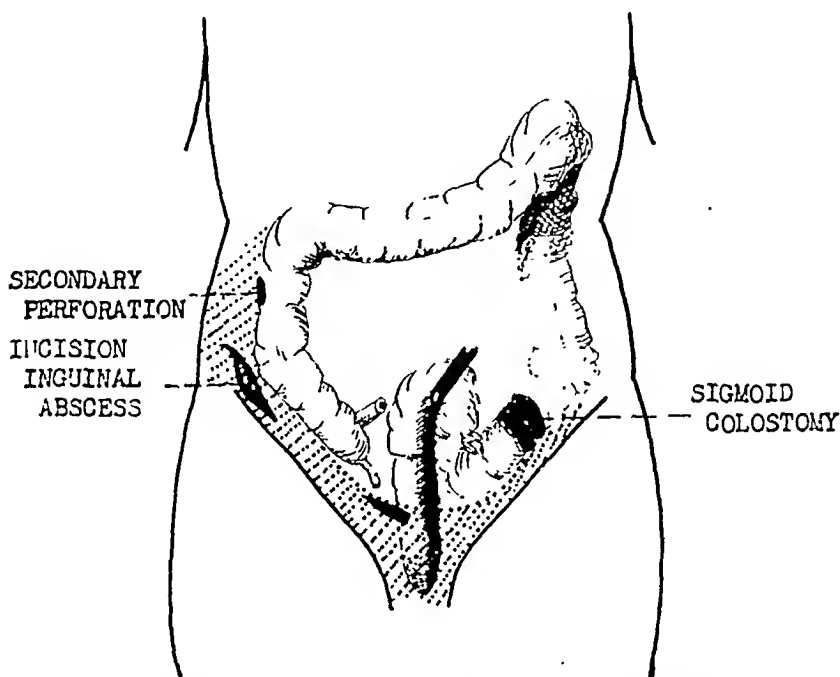


FIG. 10.—Diagram illustrating the perforation of the retroperitoneal surface of the ascending colon proximal to the sigmoid colostomy.

Within this sinus there seemed to be a sequestrum apparently detached from the ascending ramus of the ischium. On November 1, 1944, under intravenous pentothal anesthesia, the sinus was opened widely and the sequestrum removed. No attempt was made to resuture the perforation of the rectum because of the presence of infection. Following this procedure, the infection gradually subsided and the patient's general condition gradually improved.

Once the infection of the infraperitoneal space has been completely controlled, an attempt will be made again to close the perforation of the rectal wall. If this is successful and the posterior wound heals, the colostomy may be closed to reestablish intestinal continuity.

COMMENT: The ultimate result of this case is expected to be a successful one, but not without great danger and long and serious morbidity. This case differs from Case 1, first, in that colostomy was established as soon as it became clear that an extraperitoneal perforation of the rectum was present, and, secondly, in that some type of drainage of the infraperitoneal space was established immediately after injury, thus, preventing spread in undesirable locations difficult to recognize, and more difficult to reach. However, it



illustrates the inadequacy of draining the infraperitoneal space upward on the anterior surface of the lower abdomen. It, likewise, illustrates the inadequacy of drainage of the infraperitoneal space by a lateral incision



FIG. 11.—Anteroposterior radiograph after barium-filling of the rectum demonstrating the escape of barium into the infraperitoneal space.

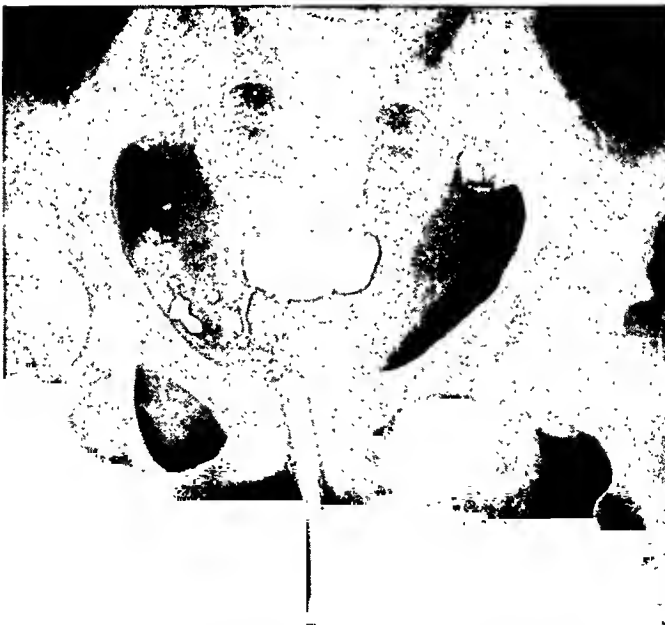


FIG. 12.—Anteroposterior radiograph after lipiodol injection of the suprapubic sinus. Note the communication along the right side of the pelvis with the large space anterior to the lower end of the sacrum. The top of the catheter lies in the suprapubic sinus.

extending through the levator (or coccygeus) and its fasciae. The incision twice failed over a long period of time to provide adequate drainage of the infection of the infraperitoneal space and to permit healing of the sinus

extending to the lower abdominal wound. These objectives, however, were readily obtained after coccygectomy.

**Case 3.**—A 22-year-old soldier sustained a bullet wound of the upper outer quadrant of the right buttock on the Italian front, September 24, 1943. A celiotomy was performed within six hours, but only an infraperitoneal pelvic hematoma was found, and the abdomen was closed without colostomy. The immediate postoperative course was moderately stormy and he soon began to drain feces through the wound of entrance. On October 23, 1943, a sigmoid colostomy was performed to divert the fecal stream. The patient continued, however, to drain a moderate amount of pus from the right buttock



FIG. 13.—Oblique radiograph demonstrating the extension of the lipiodol-filled sinus anteriorly around the rectum on the right toward the symphysis pubis. The tip of the catheter lies in the posterior wound.

and he was returned to the Zone of Interior. On arrival here, the patient was moderately septic and somewhat malnourished. There was loculation of pus in the right buttock near the wound of entrance. The celiotomy wound was well-healed and the sigmoid colostomy was functioning well. Barium enema revealed no abnormality. Proctoscopic examination revealed a deep dimpled granulation three inches above the anal orifice at three o'clock (Fig. 14). The bullet could be felt in the deep tissues of the para-anal region at nine o'clock (Fig. 15).

R. B. C. was 4.2 million per cu. mm.; W. B. C. 7,750 per cu. mm.; hemoglobin 13.5 Gm. per cent; uranalysis was normal; N. P. N. 28 mg. per cent; sugar 99 mg. per cent; plasma protein 7.39 Gm. per cent. Lipiodol injection of the wound of entrance revealed extensive ramifying fistulae in the retrorectal space (Fig. 16). On December 15, 1943, the lower rectum was exposed by coccygectomy, the perforation was closed, the fistulae were widely opened, the bullet removed from the para-anal region, and the entire retrorectal space loosely packed. This wound healed slowly but cleanly. Meanwhile, pus continued to drain from the wound of entrance in the right buttock and finally several spicules of bone appeared. Roentgenologic studies revealed osteomyelitis, with sequestration of the lower aspect of the right sacro-iliac joint. On January 19, 1944, the upper half of the bullet tract was saucerized and sequestrectomy performed. This wound healed slowly but uneventfully until May 26, 1944, when a plastic secondary closure was performed. On July 18, 1944, the posterior wounds having healed, the sigmoid colostomy

was closed. A protective cecostomy was simultaneously established because a nasal deformity precluded passing a Miller-Abbott tube. Both wounds healed uneventfully, and normal bowel habits were restored. The soldier gained in weight and strength and was returned to full duty.

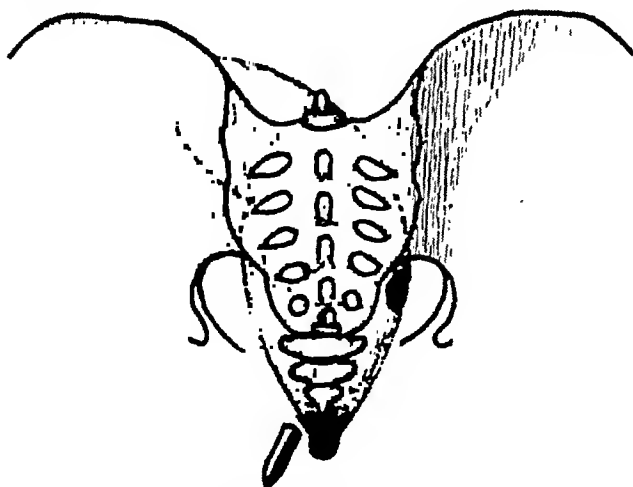


FIG. 14.—Diagram illustrating the approximate location of the perforation of the rectum. (Posterior view)

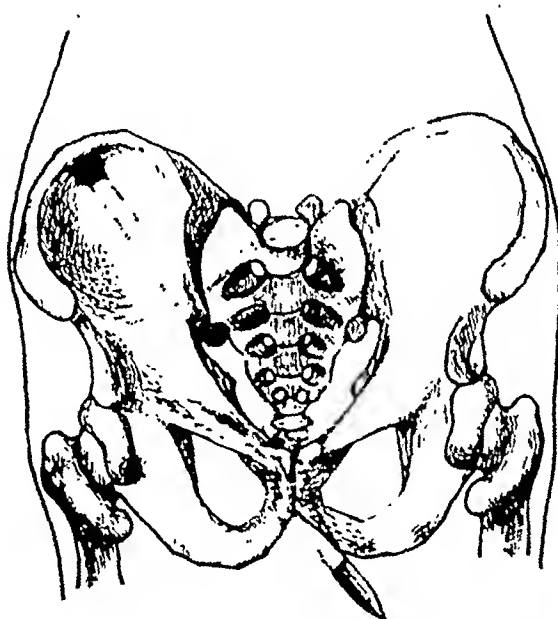


FIG. 15.—Diagram illustrating the approximate course of the bullet. (Anterior view)

COMMENT: This case had a successful outcome, but, likewise, a long and serious morbidity. It is not clear from the records how soon after trauma the perforation of the rectum became manifest by the appearance of fecal drainage from the wound, but it is probable that only a contusion of the rectal wall was present until infection of the bullet tract caused a secondary perforation. This may have saved the patient from death or more serious morbidity since the fecal contents drained into a prepared and partially walled-off fistulous tract. Because the pressure from its direct communication with the bowel was not relieved it soon honeycombed through the little resist-

ing tissues of the infraperitoneal space. Sigmoid colostomy was established one month after the injury, but the damage was already done and the honeycombed labyrinthine fistulae continued to be infected from the communication with bowel. Saucerization of the perirectal space through coccygectomy together with closure of the perforation was necessary to ablate these fistulae. The proximal intramuscular portion of the bullet tract was ignored in our first operation, and it may have been expected to heal were it not for the fact that osteomyelitis of the lower end of the sacro-iliac joint with sequestration, had developed. Once sequestrectomy was performed healing of this portion of the tract developed uneventfully.



FIG. 16

FIG. 16.—Oblique radiograph after lipiodol-filling of fistula through the wound of entrance and barium-filling of colon, both proximal and distal to colostomy.



FIG. 17

FIG. 17.—Lateral radiogram after lipiodol injection of the external fistulous tract in the right buttock revealing its entrance into the rectum.

**Case 4.**—A 30-year-old officer sustained a through-and-through gunshot wound of both buttocks while on the Italian front on July 16, 1943. He was taken prisoner but subsequently retaken by Allied troops. Meanwhile, a fecal fistula had developed in both wounds of entrance and exit and a sigmoid colostomy was, therefore, established on July 24, 1943. The wounds continued to drain pus and feculent material, and, August 16, 1943, he was returned to the Zone of Interior.

On arrival here, September 22, 1943, his general condition had improved. He was still 26 pounds below his maximal weight. The gunshot wounds had healed and his colostomy was functioning well. Proctoscopic examination failed to reveal any lesion of the lower bowel and barium studies of bowel both proximal and distal to the colostomy were essentially normal. Accordingly, October 4, 1943, the sigmoid colostomy was closed. The immediate postoperative convalescence was essentially normal. On October 19, 1943, the wound in the right buttock reopened and began to drain at first sero-sanguineous, then purulent material. Lipiodol was injected into its orifice and was found on roentgenologic examination to enter the rectum (Fig. 17). Later, methylene blue, likewise, injected, was observed entering the rectal ampulla in the middle of the

posterior wall 6.5 cm. above the anal orifice but the internal orifice of the fistula was hidden behind a rectal valve. It was decided to treat the fistula conservatively, and by November 22, 1943, the external orifice had healed completely. On January 12, 1944, this wound reopened and discharged feces. Rectal examination now revealed a palpable granuloma in the previously observed location of the internal orifice of the fistula. On January 24, 1944, the fistulous tract was excised, employing a T-shaped incision and exposing the rectum by coccygectomy. The rectal mucosa at the site of perforation was found everted and embedded into an osteoperiosteal scar in the lower segment of the sacrum in such a manner that it could never have healed. After freeing the edges of the defect in the rectum they were inverted by two purse-string sutures, the osseous defect



FIG. 18.—Posteroanterior radiograph showing lipiodol entering the rectum after injection of the external fistulous orifice. The fistula itself appears as a faint line extending to the left. Note fracture of descending ramus of right pelvis.

was curetted and the wound lightly packed and left unsutured. A transverse colostomy was established. Healing was uneventful. Penicillin was administered parenterally. On March 28, 1944, the cleanly granulating posterior wound was revised and secondary suture performed.

On May 25, 1944, the transverse colostomy was closed. Healing again was uneventful. The patient had gained in weight and strength, bowels were functioning normally, and all wounds had been completely healed for several months when the patient was returned to duty on August 12, 1944.

COMMENT: The lessons to be learned from a study of this case are invaluable. Here, again, despite the failure to establish early sigmoid colostomy and adequately drain the infraperitoneal space by coccygectomy, this patient, fortunately, developed merely a fecal fistula rather than a spreading infraperitoneal infection. The reasons for the development of a rapidly spreading infraperitoneal sepsis in some cases and a mere fecal fistula in others is unknown to us. It may be, as already suggested above, that these cases which develop fecal fistula represent late secondary perforations of a contused area of rectum into an already prepared missile tract. However, such an outcome is unpredictable and where there is presumptive evidence of rectal

injury a proximal colostomy should be established immediately as a life-saving procedure. Once a sigmoid colostomy was established, and the intraluminal pressures and gross contamination of functioning bowel removed, the fecal fistula seemed to heal. In the light of subsequent events, it appears that the external orifice and most of the fistulous tract may heal, only to reopen again if the internal orifice at the mucous membrane remains open, and the intraluminal pressure and gross contamination of normally functioning bowel is restored by closure of colostomy. The internal orifice of this fistula would never have healed because the everted edges were embedded in the scarred defect in the sacrum. This scar was not readily discovered because it lay hidden just proximal to one of the rectal valves. This case, likewise, illustrates the unreliability of demonstration of these defects with barium. Above all, it illustrates the importance of closure of the internal orifice of these rectal fistulae, with wide saucerization of the adjoining bowel surface.

**Case 5.**—A 25-year-old soldier sustained shell fragment wounds of the right buttock and left thigh March 29, 1943, in the North African campaign. He was admitted to a Surgical Hospital where the wound of the right buttock was débrided and found to communicate with the rectum. He was transferred to an Evacuation Hospital where a laceration, 3 cm. in diameter, 7 cm. above the anal orifice, was discovered. On April 2, 1943, a loop-colostomy of the sigmoid was established and opened on April 4, 1943. On April 6, 1943, a large metallic foreign body was removed from the wound of the medial aspect of the upper left thigh. The soldier escaped injury to the neurovascular structures of the left lower extremity. Both wounds healed rather slowly and a chronic fistulous tract developed in the wound of the right buttock communicating with the rectum. The patient was returned to the Zone of Interior. On arrival here, his general condition was fair. He was still some 35 pounds below maximal weight. There was a well-healed, long, lower left rectus abdominal scar through the lower end of which presented the loop-colostomy of the sigmoid. There was a clean granulating wound of the lower aspect of the right buttock about 6 cm. lateral to the anus. Near its center was the external orifice of the fistulous tract. There was a healing wound on the anteromedial aspect of the upper left thigh. Roentgenologic studies of the pelvis revealed a healing fracture of the descending ramus of the right pubis. After cleansing the rectum, proctoscopy revealed the granulating internal orifice of the fistula on the right posterolateral wall of the rectum about 7 cm. above the anal orifice. On May 13, 1943, the fistula was visualized by lipiodol injection (Fig. 18). The lipiodol readily entered the rectal ampulla. On May 30, 1943, the fistula was excised by radial incision overlying its entire extent. The sphincters were spared. The induration margins about the mucous membrane of the internal orifice were trimmed and the fresh margins inverted with fine catgut suture. The wound was then lightly packed open. It healed very cleanly by secondary union. On June 18, 1943, anoscopic examination revealed that the internal orifice was well-healed with a slightly raised margin. On July 8, 1943, the wound of the left thigh was completely healed. The operative wound of the buttock was healed except for a ribbon of clean granulation tissue at the skin level. Accordingly, July 9, 1943, the sigmoid colostomy was closed with delayed closure of extrafascial layers. Bowels functioned spontaneously and normally. Sphincter action was good. All wounds were completely healed by August 20, 1943. The patient regained his weight and was discharged to duty September 27, 1943.

**COMMENT:** This case is very similar to Case 4, except that the fistulous tract did not close at all, despite the sigmoid colostomy. After demonstrating

the fistulous tract and its internal orifice, the former was excised and the latter properly sutured. This was one of our earlier experiences and because the tract and perforation were low, a lateral approach directly over the fistula and through the levator was employed, without coccygectomy. Suture of the perforation was technically difficult and, in the light of our subsequent experiences, a coccygectomy would have facilitated the repair of the internal fistula and made healing more certain, because of better exposure and wider drainage.

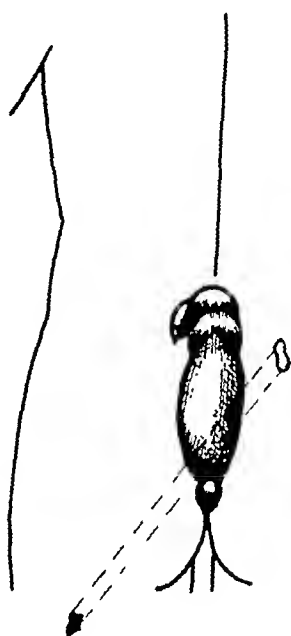


FIG. 19

FIG. 19.—Diagram illustrating the perforations of the rectal wall. (Posterior view)

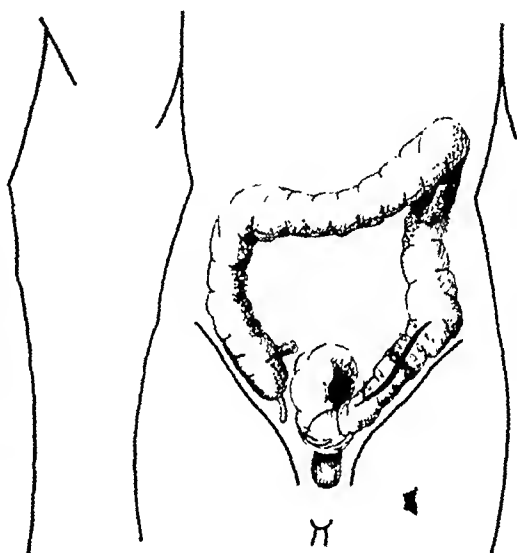


FIG. 20

FIG. 20.—Diagram illustrating the closure of the sigmoid colostomy.

Case 6.—A 36-year-old soldier sustained a mortar shell fragment wound of the right buttock, while in the process of "digging in" during the Sicilian campaign on August 7, 1943, at 1300 hours. He walked to an Aid Station three miles back where the wound was dressed, and then proceeded another ten miles on foot to an Ambulance Station where the wound was redressed. He was then transferred to an Evacuation Hospital, arriving on 1600 hours, August 8, 1943, 27 hours after the injury. At this hospital proctoscopy revealed a perforation of the rectum (Fig. 19), and sigmoid colostomy was established at once without exploratory celiotomy. His convalescence was essentially uneventful. He was transferred to the Zone of Interior. On arrival here, September 25, 1943, the general physical condition was noted to be good. A double-barrel spur colostomy presented through a well-healed left gridiron incision. There was a well-healed scar, 5 cm. long, in the upper medial quadrant of the right buttock. After cleansing the rectum, digital examination revealed a tender pit-like depression at three o'clock and another at eight o'clock, 4 cm. above the anal orifice. These areas were examined on proctoscopy and were seen to be healed wounds. Barium studies of the large bowel, both proximal and distal to the colostomy, revealed no abnormalities. On October 1, 1943, the colostomy was closed by end-to-end anastomosis intraperitoneally. The spur was not reduced in the usual manner because a large artery was readily palpable within its walls. The wound was closed, leaving a Penrose drain to the site of anasto-

mosis (Fig. 20). Convalescence was uneventful. The wound healed *per primam*, and normal bowel function was restored. The patient was discharged to a Reconditioning Center on November 12, 1943.

COMMENT: This case differs from the foregoing cases in that a perforation of the rectum was discovered very shortly after injury and a sigmoid colostomy established. Neither drainage of the intraperitoneal space nor closure of the perforation were performed, and yet the wound perforating the rectum healed uneventfully after early colostomy. This, however, does not justify the omission of these procedures. Fortunately, both the wounds of entrance and exit in the bowel wall were small and clean-cut perforations, without eversion of the mucous membrane into the wound of exit. This cannot be determined at the time of injury, however, without exploration of the bowel wall surgically.

Case 7.—A 35-year-old soldier sustained a shell fragment wound of the right buttock while lying in a slit trench, on August 7, 1943, in the Sicilian campaign. Several hours later, August 8, 1943, an exploratory celiotomy through a lower right rectus incision was performed at a nearby Evacuation Hospital. No intraperitoneal lesion was found, but there was an extensive intraperitoneal pelvic hematoma. The wound was closed without drainage and without colostomy. On August 13, 1943, he was transferred to another Evacuation Hospital, and a laceration of the rectum was found on proctoscopic examination, accordingly, a sigmoid colostomy was established through a left gridiron incision (Fig. 21). He was returned to the Zone of Interior. On arrival here, September 22, 1943, his general condition was fair except for moderate weight loss. The lower right rectus scar was firmly healed. A single stoma of the sigmoid colostomy presented through a well-healed left gridiron incision. The septum was palpable just below the surface. There was a healed wound, 2 cm. long, in the right buttock, and another, 4 cm. long, in the left. After cleansing the rectum, proctoscopic examination failed to reveal any evidence of any unhealed lesion nor was any scar of a healed lesion recognized. Roentgenograms of the pelvis revealed a metallic foreign body, 1.5 x 1 x 0.7 cm., lying in the pelvis anterior to the upper margin of the sacrum on the right. Another foreign body, 3 mm. in diameter, appeared to lie medial to the right acetabulum. Barium visualization of large bowel proximal and distal to the colostomy failed to reveal any abnormality (Fig. 22).

Accordingly, September 28, 1943, closure of the loop-colostomy was performed under spinal anesthesia, with delayed closure of the extrafascial layers of the abdominal wound. A Penrose drain was placed down to the site of suture. Postoperative convalescence was uneventful. Skin sutures were tied on the fourth postoperative day. The wound was completely healed by October 27, 1943 (Fig. 23). The patient had regained most of his weight but little of his strength. His bowels were functioning normally and spontaneously. On November 12, 1943, he was discharged to a Reconditioning Center.

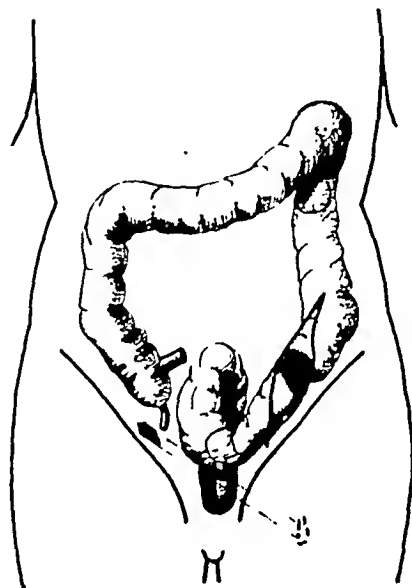


FIG. 21.—Diagram illustrating the course of the missile, the position of the foreign body, and the sigmoid colostomy. (Anterior view)



COMMENT: This is the only case in this series in which evidence of a healed fistula could not be ascertained. This does not, however, discredit the early observation of the presence of a laceration of the rectum, although the position of the lesion was not described. On the contrary, this case illustrates the wisdom of establishing colostomy even on reasonable suspicion of the presence of a perforation of the infraperitoneal rectum. We may go one step further and state that the presence of an infraperitoneal hematoma



FIG. 22.—Anteroposterior radiograph after barium-filling of the rectum.  
Note the foreign bodies in the pelvis.

from a missile traversing the infraperitoneal space, is presumptive evidence either of laceration of the rectum, contusion of its wall, or infarction from injury to its blood supply, and should be treated by prophylactic sigmoid colostomy. The danger of perforation, with its spreading infection, is thus averted or mitigated at little cost in morbidity. We may go even one step further to state that this procedure should be followed by coccygectomy with drainage of the infraperitoneal space and closure of the perforation of the rectum if one should be found. This additional procedure adds little to the operative shock and may save the patient's life or shorten his convalescence. Drainage of a potentially infected hematoma may prevent actual spreading infection, and even secondary perforation of the rectum.

## INJURIES OF EXTRAPERITONEAL RECTUM

**Case 8.**—A 19-year-old soldier sustained multiple shell fragment wounds on the Italian front on July 17, 1944, at 1000 hours. Fragments penetrated the scalp, neck, left forearm, left hemithorax posteriorly, both buttocks, and left leg. The last fragment caused a compound fracture of the left fibula, while one of the wounds of the left buttock perforated the rectum (Fig. 24). On July 18, 1944, several hours after the injuries, at an Evacuation Hospital, all these wounds were extensively débrided and foreign bodies were removed from scalp, neck and leg. A coccygectomy was performed and the infraperitoneal space adequately drained, but it is not known whether the rectal perforation was sutured. A celiotomy was performed under ether anesthesia, and a large retroperitoneal pelvic hematoma but no intraperitoneal injury was found. A sigmoid colostomy was performed. On August 1, 1944, secondary suture of wounds was performed and a skin graft was applied three days later to a wound of the elbow. The patient's convalescence was essentially uneventful. All his wounds healed rapidly and cleanly except the coccygectomy wound. This wound healed slowly and continued to drain pus and mucus. The patient was returned to the Zone of Interior. He arrived here on October 3, 1944.

On arrival, the patient was somewhat malnourished, since he was still some 40 pounds below his best weight. He was ambulatory and comfortable. His wounds were all healed except for a suspected fistula in the coccygectomy wound already noted. The presence of mucus aroused suspicion of a communication with the rectum. There

was a residual paralysis of the left ulnar nerve. The sigmoid colostomy was functioning well. R. B. C., 5.0 million per cu. mm.; W. B. C., 6,500 per cu. mm.; hemoglobin, 15.5 Gm. per cent; N. P. N., 39 mg. per cent.

Proctoscopic examination revealed a small granulating internal orifice of the fecal fistula almost directly posterior, 8.75 cm. above the anal orifice, and its communication with the external orifice in the coccygectomy scar was demonstrated both by lipiodol, and methylene blue injection (Fig. 25). Roentgenograms further revealed residual foreign bodies in the neck and chest.

On October 26, 1944, a resection of the fecal fistula was performed through the original wound. The internal orifice of the fistula was closed with two rows of No. 0000 chromic catgut. The wound was loosely packed, without closure, and has healed uneventfully, but slowly by secondary intention. The patient is now ready for closure of the colostomy to reestablish the normal channels.

**COMMENT:** This patient received almost ideal treatment. The surgeon recognized the presence of a perforation of the rectum and established adequate drainage of the infraperitoneal space by partial coccygectomy, then provided a sigmoid colostomy. It seems unlikely that the surgeon sutured the perforation of the rectum, if indeed he found it, since it lay in a position difficult of access on the left lateral wall of the rectum and the remainder of the coccyx had to be removed before it could be reached. This case illustrates, however, that wide saucerization of the infraperitoneal space, with exposure of the rectum, whether or not the perforation is sutured, is adequate

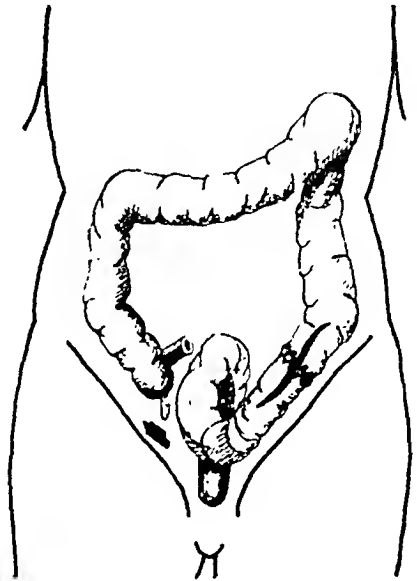


FIG. 23.—Diagram illustrating the closure of sigmoid colostomy. (Anterior view)

prophylaxis against the death-dealing infraperitoneal sepsis. Failure to suture the perforation of the rectum, however, resulted in this case in the development of a chronic fistula. The presence of such a fistula, if it is short and thick-walled, is not incompatible with a fairly good state of health. Such fistulae once well-established, rarely heal spontaneously and require excision or at least closure of the internal orifice in the bowel wall.

**Case 9.**—A 30-year-old soldier sustained multiple shell fragment wounds on the Italian front at 1200 hours on May 23, 1944. These fragments penetrated the coccygeal region and the right buttock and perforated the left knee. At 1820 hours, under gas-

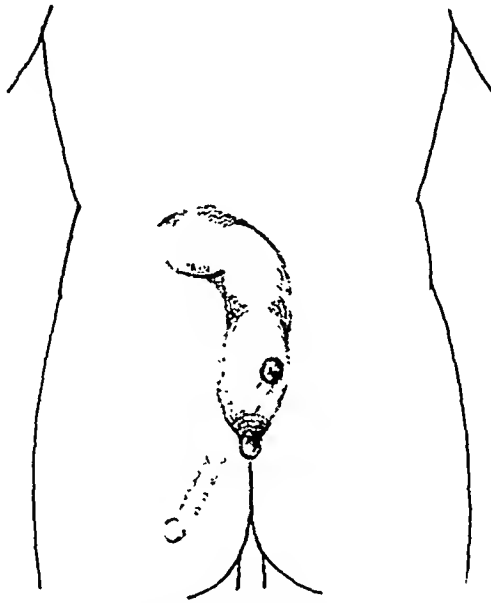


FIG. 24.—Diagram illustrating the perforation of the rectal wall. (Posterior view)

oxygen-ether anesthesia, operation was performed. On abdominal exploration through a lower midline incision, six small perforations of the ileum and one of the bladder were sutured, a sigmoid colostomy and suprapubic cystostomy were established. The abdominal wound was closed about a suprapubic catheter, leaving a rubber tissue drain in the space of Retzius. Coccygectomy was performed, the rectum exposed, the perforation was found and sutured, and the infraperitoneal space loosely packed. The other wounds were débrided and a foreign body removed from the wound of the left knee.

Convalescence was essentially uneventful. The suprapubic catheter was removed on June 12, 1944. A urethral catheter was introduced on June 16, 1944, and removed on June 23, 1944. Since then the bladder has functioned quite normally.

Before the coccygectomy wound had healed, an artery forceps was applied to crush the spur of the sigmoid colostomy but, fortunately, this was rather ineffectual, since little fecal material has passed into the rectum. Meanwhile, the coccygectomy wound failed to heal completely and a sinus developed which drained mucus and pus. The patient was returned to the Zone of Interior.

On arrival here, October 3, 1944, the patient appeared well-nourished, ambulatory and comfortable. His wounds were completely healed except for the coccygectomy wound, in the center of which there was a granulating orifice, 0.5 cm. in diameter, draining a moderate amount of mucopus.

R. B. C., 4.37 million per cu. mm.; W. B. C., 5,700 per cu. mm.; hemoglobin, 12.5

Gm. per cent. Proctoscopic examination revealed a small granulating perforation, the internal orifice of the suspected fecal fistula, 7.5 cm. above the anal orifice, directly posterior. That this was the internal orifice of the fecal fistula whose external orifice was present in the coccygectomy scar, could not be demonstrated either by lipiodol or methylene blue injection, but was finally demonstrated by the passage of a urethral catheter into the lumen of the rectum.

On October 13, 1944, the fistulous tract was excised. The internal orifice was sutured, the investing fascia approximated and the wound lightly packed. Early in the postoperative course, the suture line closing the perforation in the rectal wall, partly reopened. The mucous membrane did not become everted and, with conservative treatment, healing occurred. The wound was allowed to heal by secondary intention. The patient is now ready for closure of the colostomy.



FIG. 25.—Lateral radiograph after lipiodol injection of external fistulous orifice.

COMMENT: This patient received ideal treatment; not only was a sigmoid colostomy established and the infraperitoneal space properly drained, but the perforation of the rectal wall was found and sutured. Unfortunately, this first closure did not hold and the perforation became reestablished. As in the last case, this merely increased the morbidity without endangering the patient's life. The success of the second closure was threatened. This case illustrates the importance of freeing the mucous membrane about the edges of the defect, trimming away indurated margins and properly inverting the edges with a fine suture. If this is done the break-down of the fascial suture line will probably not jeopardize the closure of the perforation by eversion of the mucous membrane through the reopened fascial defect.

This case, likewise, illustrates the difficulty in demonstrating the entire fistulous tract by employing any one method. In this case, three separate methods were used before success was achieved.

**Case 10.**—A 32-year-old soldier sustained a mortar shell fragment wound of the left buttock on the Italian front, April 8, 1944, at 1830 hours, while at the latrine in his company area. He tried to walk back to his quarters, but collapsed. He was transported to a nearby Clearing Station, and thence to a Field Hospital where operation was performed a few hours later on April 9, 1944. Under endotracheal ether anesthesia, the wound of the buttock was débrided and perforation of the rectum discovered. Through a midline coccygeal incision, the coccyx was resected, the rectum exposed, the perforation closed and the infraperitoneal space loosely packed. Through a lower left

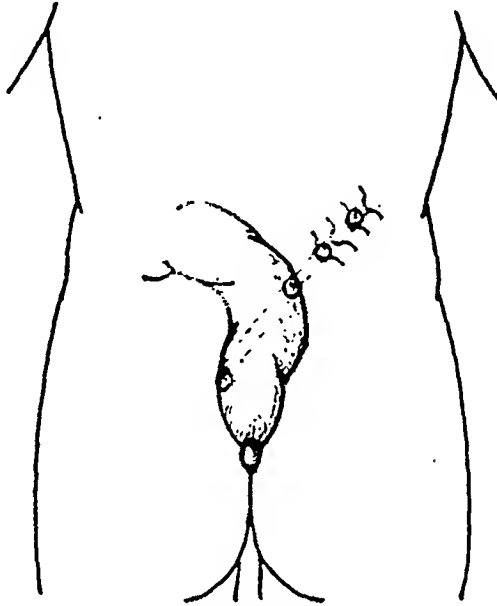


FIG. 26.—Diagram illustrating the course of the missile and perforations of rectum and two loops of small bowel. (Posterior view)

rectus incision, the peritoneal cavity was opened and several perforations of the ileum were discovered and closed (Fig. 26). Then a spur-type of sigmoid colostomy was performed through a left gridiron incision. Sulfadiazine was administered postoperatively. The postoperative course was very satisfactory, and the patient became neither septic nor malnourished. There was some delay in the healing of the transcoccygeal wound due to a sequestering osteomyelitis of remaining coccyx. The sequestrum was removed, May 9, 1944, and thereafter the wound healed uneventfully. The patient was transferred to the Zone of Interior on July 23, 1944. On admission, the patient's general condition was good. The sigmoid colostomy was functioning well, the wounds were healed, and he had no complaints. Barium studies of the large bowel and proctoscopy failed to reveal an unhealed internal fistulous orifice. R. B. C., 4.4 million per cu. mm.; W. B. C., 8,700 per cu. mm.; hemoglobin, 14.5 Gm. per cent. Urinalysis was negative. N. P. N. was 34. mg. per cent; chlorides, 495 mg. per cent; plasma protein, 7.2 Gm. per cent. After a satisfactory period of observation and recuperation, the sigmoid colostomy was closed extraperitoneally on October 13, 1944. The postoperative convalescence was again uneventful. Rectal evacuations were normal and spontaneous, and he has gained weight. He was transferred to Reconditioning Center on December 8, 1944.

**COMMENT:** This case illustrates the acme of the current ideal management of infraperitoneal perforation of the rectum. Besides establishing a sigmoid colostomy and saucerizing the infraperitoneal portion of the rectum

the perforation was found and closed. It remained closed and healing occurred quite uneventfully.

All the cases presented above received excellent and early supportive treatment of plasma, blood and chemotherapeutic agents. The difference in their subsequent clinical courses, as we have already indicated, was primarily dependent on the type of surgery and the time of its application. It is probable that many who did not receive early and adequate surgery did not survive to return to the Zone of Interior. The effectiveness of early and adequate surgery in influencing the mortality and morbidity in intraperitoneal rectal wounds is so obvious that it cannot be overemphasized. We have reached the following conclusions as a result of our observations:

#### CONCLUSIONS

1. Perforation of the intraperitoneal portion of the rectum results in fecal contamination of the cellular tissue of the intraperitoneal space. This space communicates with the retroperitoneal space posteriorly over the sacrum and may, thus, result in fulminating and widespread retroperitoneal sepsis.

2. Even if the perforation cannot be located, but there is a presumptive evidence of its presence or potential development from contusion or infarct of the rectum as judged from the course of the missile and the presence of a large hematoma in the intraperitoneal space, an effective sigmoid colostomy should be established at once.

3. A sigmoid colostomy alone will not prevent infection of the intraperitoneal space, although the infection is likely to be less widespread and fulminating once contact with the normal intraluminal pressure and gross contamination of normally functioning bowel is severed. In addition, the intraperitoneal perirectal space must be saucerized by coccygectomy and loosely packed.

4. Mere saucerization of the perirectal space, while life-saving and prophylactic against spreading retroperitoneal sepsis, is not, however, complete ideal treatment. Unless the perforation is located and closed, a persistent fistula may develop.

The authors wish to acknowledge their appreciation of the contributions made by Major Hazen L. Hauman and Major Joseph M. Miller in the clinical management of the cases presented, and Major A. Bradford Soule in the radiologic studies and photographic reproductions.

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## THE SIMULTANEOUS OCCURRENCE OF ACUTE APPENDICITIS AND MALARIA

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SEVERAL COMMUNICATIONS have appeared during the past ten years concerning the frequency with which acute malaria, when associated with abdominal symptoms, may simulate acute surgical disease of the abdomen.<sup>1-7</sup> In two of these papers instances of acute surgical disease of the abdomen were reported as occurring during an acute attack of malaria. Taylor<sup>5</sup> concluded that the differential diagnosis between so-called abdominal malaria and the "acute surgical abdomen" was not particularly difficult, and stated that the necessity of making a differential diagnosis rarely occurred. Our experience, during a period when a large number of patients suffering from malaria were admitted to this Hospital would not substantiate Taylor's complacent attitude.

In the large group of patients suffering from acute malaria we have seen innumerable instances of Castellani's<sup>1</sup> appendicular syndrome, both the acute and chronic forms, cholecystitis syndrome, acute pancreatitis syndrome, and peritonitis syndrome. In certain instances the patients have been seen in consultation with our colleagues on the Medical Service, and in others they have been admitted directly to Surgical Wards because the clinical picture appeared clearly to point to an acute surgical condition.

The clinical picture has, at times, been further confused by the superimposed abdominal symptoms which accompany plasmochin, and, to a much lesser degree, atabrine therapy.

Even the most astute diagnostician will occasionally operate upon a patient for supposed acute appendicitis with malaria, only to find at operation no evidence of an acute surgical abdominal lesion, and, on the other hand, may delay operation until peritonitis makes the diagnosis unmistakable.

We have, during the period when acute malaria was prevalent in this area, operated upon ten patients who simultaneously had acute malaria and acute appendicitis; one who had acute malaria and a perforated duodenal ulcer, and two with acute malaria and spontaneous rupture of the spleen. In three instances at operation for supposed acute appendicitis, the appendix was found not to be inflamed. A brief analysis of the patients with appendicitis is presented in order to point out the difficulties encountered in the differential diagnosis between malaria simulating, or associated with, symptoms of acute appendicitis, and acute appendicitis occurring during a period of acute malaria. These difficulties are further multiplied by the frequency with which patients who are receiving plasmochin develop acute abdominal pain, right-sided tenderness, nausea and vomiting, and even abdominal rigidity during therapy for acute malaria.

Daniel<sup>7</sup> has pointed out that the improvement of the patient's symptoms on antimalarial therapy is a strong indication that malaria is the cause of the patient's abdominal symptoms, while failure to show improvement is an indication that an acute surgical lesion is present. Our experience with the newer forms of antimalarial therapy leads us seriously to question this conclusion, for in many instances we have seen violent abdominal symptoms develop and persist during plasmochin and occasionally during atabrine therapy, making the clinical picture and the differential diagnosis more complex and difficult, rather than less so.

Table I gives the pertinent data in the ten patients with acute malaria proven to have acute appendicitis at operation, and of the three patients operated upon in whom a normal appendix was found.

DISCUSSION.—Of the ten patients proven to have acute appendicitis at operation seven had acute diffuse suppurative appendicitis, or worse, according to the pathologic report and three had acute simple appendicitis. Of the seven patients with malaria and acute diffuse suppurative appendicitis, the white blood cell count varied from 4,100 to 15,000 (mean count 10,175); in the milder cases from 5,600 to 6,350 (mean count 6,680); and in those with a normal appendix 9,330. The count was highest in the suppurative group, but in only three of the seven patients was it above 12,000.

In two, the type was undetermined; three patients were infected with *P. falciparum*, and five with *P. vivax*. In Daniel's series of nine patients with malaria simulating acute abdominal disease seven were infected with *P. vivax* and two with *P. falciparum*. In the three cases where a normal appendix was found two had *P. falciparum* and in one the type was undetermined. It is usually considered that abdominal symptoms are more accentuated in *P. falciparum* infection.

In only four of the seven patients with suppurative appendicitis a chill occurred prior to admission. Pain in the right lower abdominal quadrant was present in all cases, as was tenderness. Five of the seven suppurative cases had rebound tenderness and a similar number rigidity, but these findings were by no means pathognomic of what we found at operation.

Even the temperature at the time of admission was of no significant help, for in at least one patient with perforation of the appendix the temperature was 103° F., and in others the temperature was normal or nearly so, as it frequently is between chills. The findings of parasites in the smear, leukopenia, a chill and a sharp rise in the febrile reaction could by no means be taken as indicative that an acute surgical abdominal lesion was not present. Nausea, and to a lesser extent vomiting are equally frequent in both conditions.

#### CONCLUSIONS

It should be freely recognized that the differential diagnosis between acute malaria with acute nonoperative abdominal symptoms and acute malaria and an accompanying acute surgical lesion of the abdomen is difficult and,



at times, not possible before operation discloses the true state of affairs. In certain instances with milder symptoms operation may be delayed while intensive antimalarial therapy is being instituted. It is, however, urged that even in these, if the abdominal symptoms and signs do not change for the better, operation be not too long delayed. If this be done the signs of

TABLE I

SYNOPSIS OF DATA ON 13 PATIENTS WITH CONCURRENT MALARIA AND SYMPTOMS OF ACUTE APPENDICITIS

Patient	Chill	R.L.Q. Pain	R.L.Q. Tender-ness	Rebound Tender-ness	Rigid-ity	W.B.C.	Nausea	Vomit-ing	Malaria Smear	Findings at Operation
Case No. 1	+	+	+	+	0	11,100	+	+	Type un-determined	Acute diffuse suppurative
Case No. 2	0	+	+	+	+	4,100	0	0	<i>P. falciparum</i>	Acute diffuse suppurative
Case No. 3	+	+	+	0	+	9,100	+	+	<i>P. falciparum</i>	Acute diffuse suppurative]
Case No. 4	+	+	+	+	+	14,700	0	0	<i>P. vivax</i>	Acute diffuse suppurative
Case No. 5	0	+	+	0	0	13,600	+	0	<i>P. vivax</i>	Acute diffuse suppurative
Case No. 6	+	+	+	+	+	15,000	+	0	<i>P. vivax</i>	Acute diffuse suppurative
Case No. 7	0	+	+	+	+	4,150	0	0	<i>P. falciparum</i>	Acute diffuse suppurative
Case No. 8	0	+	+	+	0	7,350	0	0	<i>P. vivax</i>	Acute simple
Case No. 9	+	+	+	0	±	5,600	0	0	<i>P. vivax</i>	Acute simple
Case No. 10	0	+	+	+	+	7,100	+	0	Type un-determined	Acute simple
Case No. 11	+	+	+	+	+	11,800	0	0	<i>P. falciparum</i>	Appendix normal
Case No. 12	0	+	+	0	+	9,600	+	0	Type un-determined	Appendix normal]
Case No. 13	+	+	+	0	0	6,700	+	0	<i>P. falciparum</i>	Appendix <sup>1</sup> normal

spreading peritonitis will finally force the unwilling clinician to make the diagnosis of an abdominal catastrophe. No reliance can be placed on the symptoms, signs, and type of infection found by smear in attempting to determine with absolute accuracy the differentiation of these two groups of cases.

It is worth while remembering that when a large number of individuals suffering from acute malaria are seen there are apt, also, to be seen individuals who simultaneously are suffering from acute surgical disease of the abdomen.

In the three patients in whom no surgical disease of the appendix was found, in only one was endothelial hyperplasia of the lymph nodes in the terminal mesentery of the small bowel sufficiently extensive to account for the patient's abdominal symptoms. The differential diagnosis is often exceedingly difficult, and at times impossible. Where the physical signs and symptoms strongly suggest an acute surgical abdominal lesion it is safer not to delay operation too long unless prompt improvement of the abdominal symptoms and signs follow antimalarial therapy.

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# RIGHT PARADUODENAL HERNIA

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RIGHT PARADUODENAL HERNIA is a rare surgical condition. Only two patients with this condition have been seen at the Lahey Clinic from 1925 to 1944. This incidence corresponds with that stated in the literature. From 1910 to 1939 there were two cases of right paraduodenal hernia treated surgically at the Mayo Clinic.<sup>5</sup> The ratio of right paraduodenal hernia to left paraduodenal hernia is 1 to 3. In 1941, Cogswell and Thomas<sup>3</sup> found a total of 48 cases of right paraduodenal hernia reported in the literature. Operation was performed in 29 of these 48 cases, with recovery in 16 cases. Thus, the mortality has been almost 50 per cent, and probably is higher when we consider that only the cases in which operation was successful are likely to be reported. We are adding two cases in which operation was performed, with recovery, to the total of 16 cases.

Right paraduodenal hernia was defined by Moynihan<sup>7</sup> as having the following characteristics: (1) Almost all of the small intestine is imprisoned in a peritoneal sac behind the ascending and transverse mesocolon and occupies the right half of the abdomen; (2) the opening of the sac is to the left and near the duodenojejunal juncture at the ligament of Treitz; and (3) the superior mesenteric artery or a continuation of it, the ileocolic artery, lies in the anterior portion of the sac. It is for this reason that the surgical correction of this hernia often presents technical difficulties because the vascular supply to the small bowel may be impaired. This hernia is also called internal hernia, retroperitoneal hernia, and intraperitoneal hernia.

Andrews<sup>1</sup> stated that right paraduodenal hernia is the result of malrotation of the ascending colon and cecum. An excellent description with explanatory diagrams of normal and abnormal rotation of the cecum causing right paraduodenal hernia is given by Cogswell and Thomas and will therefore not be repeated.

## CASE REPORTS

Case 1.—A white male, aged 47 years, was first seen at the Lahey Clinic on December 6, 1943. The chief complaint was intermittent episodes of diarrhea for 15 years, recurring about once or twice a year. The attacks lasted three days, with associated fever and chills. There was no nausea or vomiting. The stools were light in color and did not contain blood. The episodes of diarrhea increased in frequency until 1940 when he started drinking a quart of buttermilk a day; the periods of diarrhea stopped for two years. In 1942 they reappeared, with a feeling of heaviness in the abdomen. During the past year diarrhea recurred at three week intervals, lasted three days and usually followed a train ride. The diarrhea was so severe that he had

almost continuous stools for hours. The episodes were not related to the ingestion of any special food or to the time of eating. The onset was always sudden and accompanied by fever. He took vitamin B-complex for three months which improved the diarrhea, but chills and fever without pain or abdominal cramps still occurred. There was almost continual gnawing, hunger-like distress in the midepigastrium, unrelieved by eating. No weight loss was admitted. Roentgenograms had not been taken. Four years before coming to the Clinic his stools were examined for parasites, and were negative. The past history and family history were essentially negative.



FIG. 1.—Case 1: Barium enema showing the cecum not filling out well, being concave on the medial side.

On physical examination the patient was moderately obese, weighing 214 pounds. The significant observations were limited to the abdomen which showed tenderness in the right and left lower quadrants.

The patient was admitted to the hospital for study. The gastro-enterologic roentgenograms of the esophagus, stomach, duodenum and small intestine were reported to be normal. The barium enema revealed that the cecum did not fill-out well (Fig. 1), being concave on the medial side. An air contrast enema showed that the entire colon was

distended with air, but the cecum did not distend to a rounded contour on its medial surface. Gastric analyses and roentgenograms of the gallbladder were normal.

Because of the questionable defect in the cecum an exploratory celiotomy was performed under spinal anesthesia by one of us (F. H. L.) on December 17, 1943. A hernia was found which originated in the right paraduodenal fossa through a defect beneath the root of the jejunal mesentery (Fig. 2). Through this defect all the small bowel had herniated and was completely encased in the hernial sac of peritoneum of the

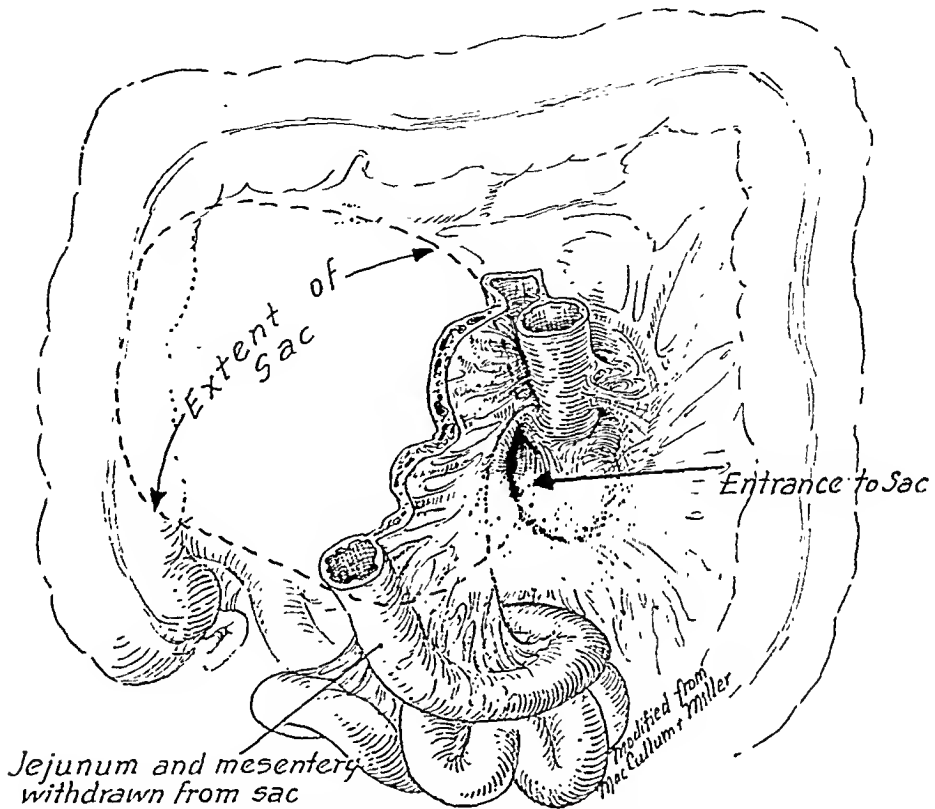


FIG. 2.—Entrance to hernial sac near ligament of Treitz and extent of hernial sac behind mesocolon of ascending colon.

proximal jejunal mesentery and the peritoneum of the ascending and transverse mesocolon (Fig. 3). There was no obstruction of the bowel. There was some angulation at the ileocecal area with some thickening of the terminal ileum as it emerged from the hernial sac to enter the cecum normally. An opening was made in an avascular area of the mesocolon of the ascending colon. Beneath this the hernial sac of the mesentery of the proximal jejunum was incised in an avascular area. The small bowel was freed from it, and the sac traced down to its root at the jejunal fossa where the large defect was found in the mesentery of the jejunum entering from the left. The sac was carefully dissected off the jejunum and the third portion of the duodenum. The neck of the sac was closed with atraumatic chromic catgut, and the redundant portion of the sac was excised (Fig. 4). The intestines were pulled back into the greater peritoneal cavity in their normal position. The peritoneum of the ascending colon was closed with atraumatic sutures, thus peritonealizing the posterior abdominal wall on the right side.

The postoperative course was uneventful, and the patient made an excellent recovery. He was discharged on the 18th postoperative day.

A letter from the patient, dated March 3, 1944, stated that he was "not able thus far to find the slightest trace of the old symptoms."

**Case 2.**—A 17-year-old white girl was first seen at the Lahey Clinic on April 21, 1944, with the chief complaint of acute attacks of abdominal pain since birth. The attacks of pain occurred in the upper abdomen, and were followed by nausea and vomiting. The vomiting eventually brought relief. The pain was well localized and did not radiate, was severe, but did not require morphine. There was no back pain. Between attacks, digestion and function of the bowel were normal.



FIG. 3.—Case 1: Appearance of the small intestine as though contained in a spherical transparent paper bag.

Physical examination gave essentially negative results. The gastric analysis showed free acid of 45, total acid of 76, and occult blood, 0. On April 25, 1944, a roentgenogram of the esophagus, stomach, and duodenum was considered normal. On May 28, 1944, a second roentgenogram of the duodenum was considered to show malformation of this structure. A third roentgenogram taken on June 14, 1944, was interpreted as showing redundancy of the duodenal loop and absence of the usual ascending loop of duodenum to the duodenojejunal angle (Fig. 5). The jejunum was largely on the right side of the abdomen. The jejunal mucosal pattern was normal. A barium enema (Fig. 6) and roentgenogram of the gallbladder were normal.

Because of the recurring attacks of pain and the abnormal roentgenologic findings,

an exploratory celiotomy was performed on October 31, 1944, by one of us (F. H. L.). A herniation of the proximal portion of the jejunum through the mesentery of the jejunum at the ligament of Treitz was found. Approximately two feet of the jejunum had herniated through the right paraduodenal fossa. There was angulation of the jejunum at the ligament of Treitz. The hernial mass had partially raised the peritoneum of the right upper posterior abdominal wall medial and inferior to the hepatic flexure of the colon. The jejunum was pulled out of the hernial sac. The angulation of jejunum was then straightened by sharp and blunt dissection. The opening of the hernial sac was sutured with fine interrupted silk sutures. A small portion of the jejunum was then buttressed against the opening with interrupted silk sutures (Fig. 4).

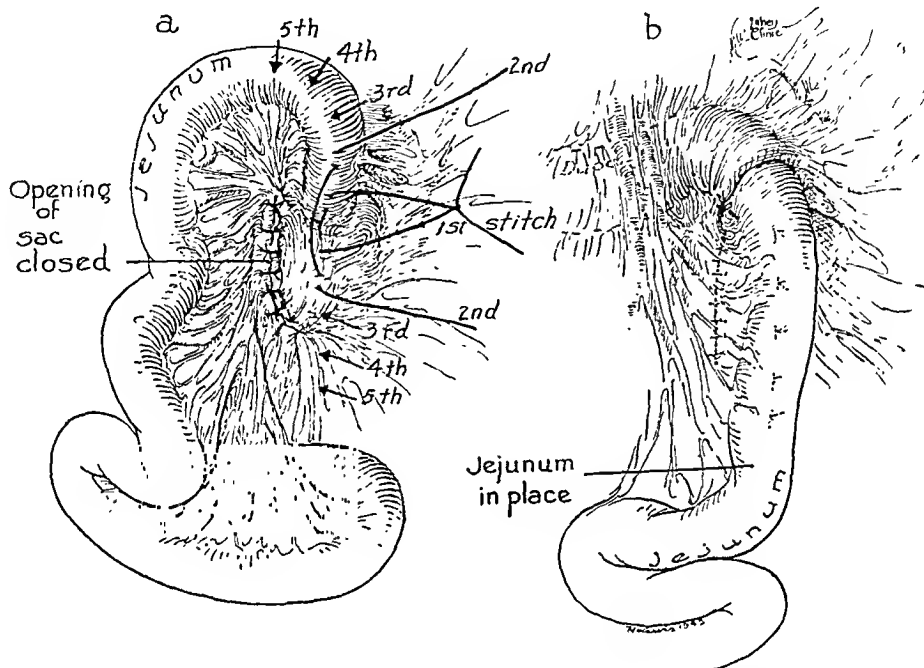


FIG. 4.—Closure of entrance of hernial sac and buttress of proximal jejunum over this closure.

The patient's convalescence was uneventful until the 12th postoperative day, when she had an attack of abdominal pain with considerable vomiting. Wangenstein suction was instituted and intravenous fluids were administered. The following day, November 14, 1944, a partial gastro-intestinal roentgenographic series was made which was reported as follows: Films taken at hourly intervals for six hours showed only a small amount of barium in the loops of small bowel at one hour. At the two-hour examination, barium was scattered through the loops of small bowel, with the head of the meal in the cecum. At six hours there was a large gastric residue, with the duodenal loop also visualized and appearing dilated. The interpretation was marked pylorospasm and dilatation of the duodenal loop.

Following this complication, the postoperative course was without incident, and the patient was discharged four days later, on the 17th postoperative day.

COMMENT.—In reviewing the preoperative roentgenograms (Figs. 3 and 5), it is of particular interest that in Case 1 (Fig. 3) the correct diagnosis might have been made because of the following differential points, as described by Exner<sup>4</sup>: (1) The appearance of the small intestines, as though they were contained in a spherical transparent paper bag from which restricted position

it is usually impossible to disturb the intestinal coils by manual palpation or postural change; (2) the location of the small intestines well above the true pelvis. Normally, the ileum gravitates and lies in the rectovesical pouch. The concavity visible on the medial aspect of the cecum in the preoperative barium enema is now interpreted as being caused by extrinsic pressure on the cecum from the overlying hernial sac (Fig. 1).



FIG. 5.—Case 2: Roentgenogram showing (1) abnormal location of the jejunum on the right side of the abdomen (2) downward continuation of the jejunum from the second portion of the duodenum; and (3) absence of the transverse third and ascending fourth portions of the duodenum traveling to the left across the spine.

In Case 2, the following positive roentgenographic findings diagnostic of right paraduodenal hernia are well illustrated (Fig. 5) and should have led to the suspicion of a right paraduodenal hernia: (1) The abnormal location of the jejunum on the right side of the abdomen; (2) the downward continuation of the jejunum from the second portion of the duodenum; (3) the absence of the transverse third and ascending fourth portions of the duodenum traveling to the left across the spine; and (4) the dilatation of the duodenum as a result of constriction or angulation of the proximal part of the jejunum by the neck of the peritoneal sac, thus causing the symptoms of high intestinal



obstruction, with relief by vomiting. These differential points were emphasized by Case and Upson.<sup>2</sup>

The two cases reported here are very similar to the case reported by McCarty and Present<sup>6</sup> in that there was no evidence of malrotation of the cecum (Figs. 1 and 6), and is explained on the same basis as in their case. It is supposed that one or more loops of small intestine were caught at an

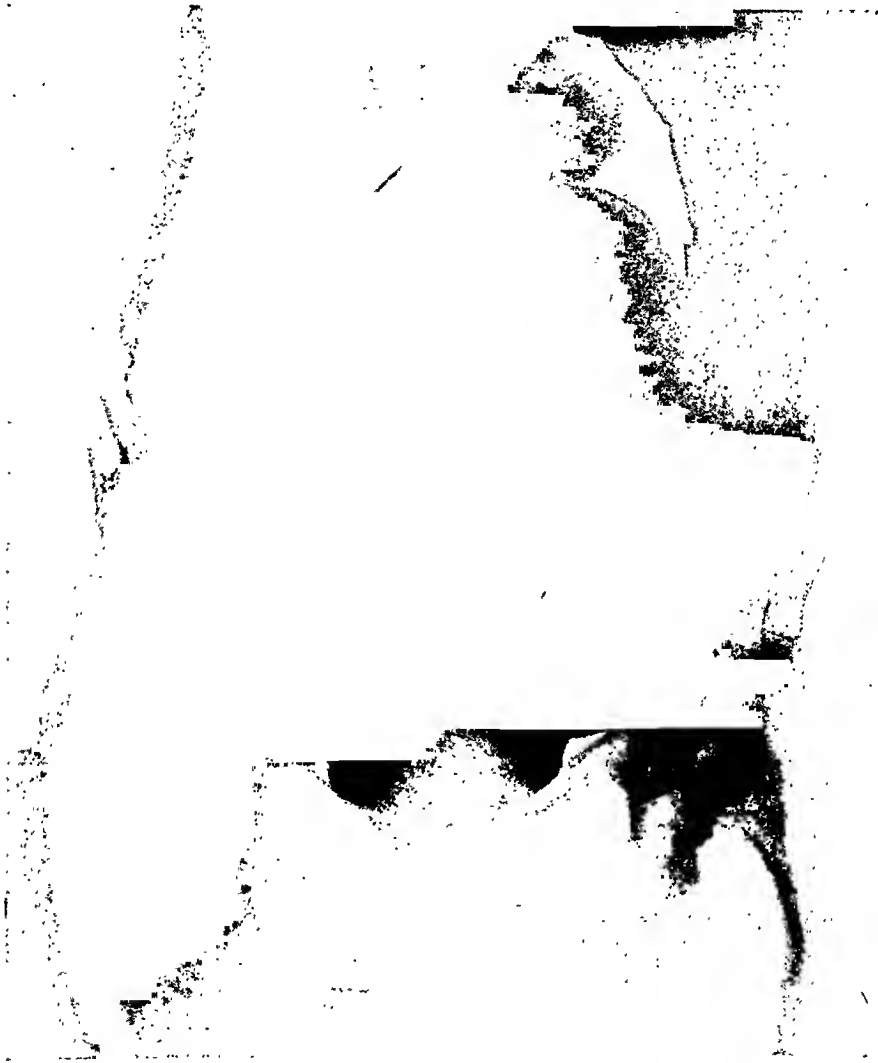


FIG. 6.—Case 2: No evidence can be seen of malrotation of the cecum in this barium enema.

early embryologic stage in a pouch formed by the extraordinarily long mesentery of the proximal jejunum (Fig. 7). As the length and size of the small intestine increased, the hernia increased.

Since right paraduodenal hernia is most commonly found incidental to operation performed for another surgical condition or as the result of an exploration, it is important in every patient with unexplained and persistent abdominal symptoms that the region of the ligament of Treitz be included in general exploration with the possibility of the undiagnosed

existence of such a hernia. Most of these herniae are symptomless for a long time, but if found and reducible, the small intestine should be pulled back into the general abdominal cavity and the aperture left behind, obliterated and buttressed over by the adjacent loop of jejunum to reinforce it (Fig. 4).

The most common presenting symptom of this condition is a varying degree of intestinal obstruction, either partial or complete. Having in mind

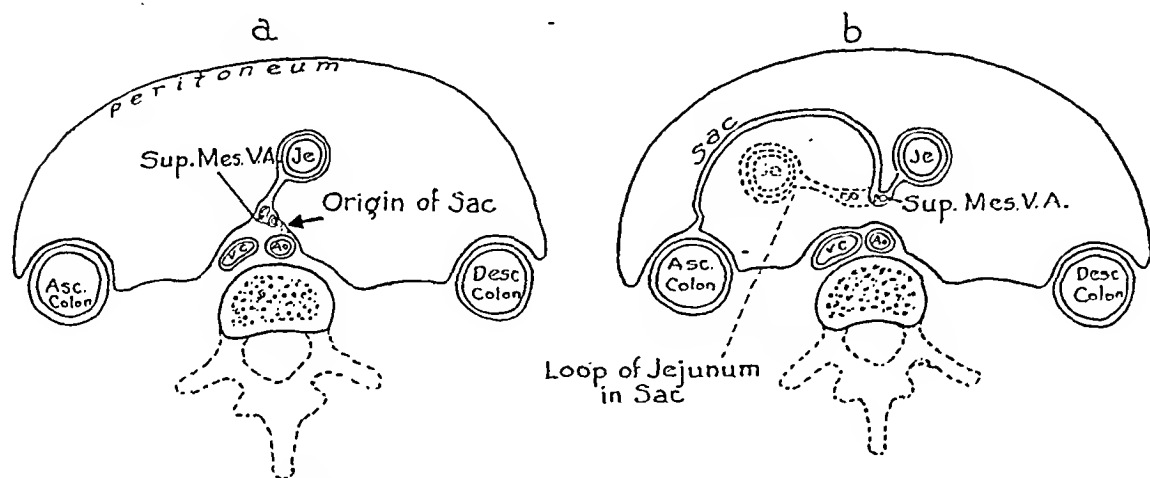


FIG. 7., a and b.—Cross-section showing origin of hernial sac and its progressive growth with loops of small intestine contained within the growing sac.

the diagnostic roentgenographic features, as described by Exner, and which are present in this series, a preoperative diagnosis, at least in such cases as ours, should be reasonably possible.

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# BENIGN CAPILLARY HEMANGIOMA OF DIGITAL FLEXOR TENDON SHEATH\*

## CASE REPORT

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HEMANGIOMAS of tendon sheaths are sufficiently rare that an additional case seems worth reporting. Harkins, in 1937, collected 24 cases from the

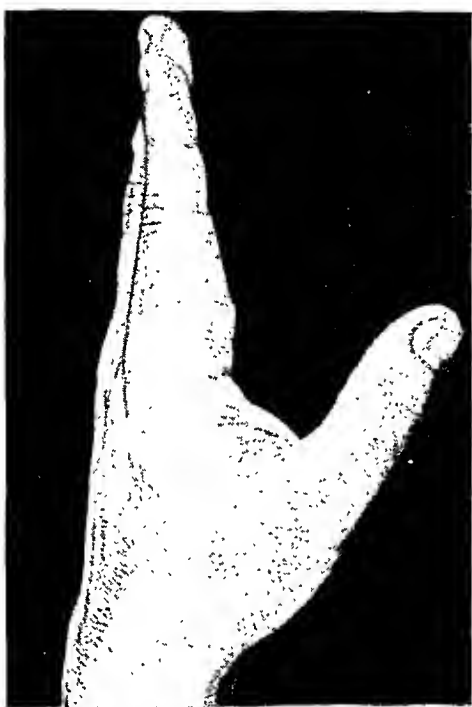


FIG. 1.—Left index finger, fully extended, showing abnormal fullness at the base of the proximal phalanx and overlying the distal head of the second metacarpal.

literature, including both hemangiomas of the tendon and tendon sheath. He reported 16 cases previously reported by Berman and Milgram, collected eight more from the literature, and added a case of his own. Of the cases listed, only four involved the fingers. They are more common in the forearm and wrist than in the hand. King, in his review of tumors of tendon sheaths, does not mention hemangioma. Mason, in discussing tumors of the hand, mentions angiomata as quite rare, but does not give specific instances. Morton, writing about tumors of tendon sheaths, lists one case of a fibrohemangioma of the tendon sheath of the wrist, but mentions none in the fingers. From his microscopic description and photomicrograph, the tumor was probably similar to that in the present case.

**Case Report.**—*Hemangioma of the Flexor Tendon Sheath of Left Index Finger:* H. S., white, male, age 22, was admitted to the Naval Hospital, December 19, 1943, for treatment of a gunshot wound of the left cheek and left thigh which had been incurred on December 13, 1943, during an argument with a civilian. The injury to the cheek was trivial, but the bullet had fractured the left femur in the supracondylar region. Family and past history were noncontributory.

**Physical Examination.**—This was essentially negative except for: 1. A small crusted wound of the left cheek, which was very superficial. 2. A compound, comminuted fracture of the left femur. 3. A slightly tender swelling at the base of the left index finger on its volar surface.

\* The opinions or assertions contained herein are the private ones of the writer, and are not to be construed as official or as reflecting the views of the Navy Department or the Naval Service at large.

*Laboratory Data:* R. B. C. 3,200,000 Hb. 9.5 Gm., or 66 per cent, W. B. C. 9,800, neutrophils 77 per cent, lymphocytes 7 per cent, eosinophils 3 per cent, basophils 1 per cent, monocytes 12 per cent. Urinalysis: Negative. Blood Kahn: Negative.

The patient was treated for the fractured femur by the Orthopedic Service, and when essentially well and convalescing from this condition, was transferred to the Plastic Surgical Service, June 2, 1944, for treatment of the painful swelling at the base of the left index finger.

Reëxamination at this time showed the lesion on the cheek to be completely healed, with practically no scar. The femur was solidly united and motion in the knee joint was fairly good and showing steady improvement. The swelling at the base of the left index finger was not appreciably larger than at first examination. This consisted of a soft,



FIG. 2.—Roentgenogram of left hand showing irregularity of radial aspect of the proximal index digit. There is also some condensation of bone along the cortex in this area.

moveable, poorly defined tumor mass lying in the subcutaneous tissues at the volar and radial aspects of the proximal phalanx of the index finger. There was no discoloration of the tissues overlying this mass, and no other vascular or nervous disturbances were noted. The mass became most prominent when the finger was completely extended (Fig. 1). It was not tender to palpation, except with heavy pressure, but when the patient attempted to make a tight fist, he was unable to flex the finger completely without pain. The tendons moved freely and did not appear to be adherent to the mass.

*Roentgenologic Examination.*—Lt. Comdr. Robert K. Arbuckle, M.C., U.S.N.R.: "The left hand shows deformity of the proximal phalanx of the index finger on its lateral aspect. There is erosion of the bone at this point, just beyond the metacarpophalangeal joint, but there is also increased density of the cortex with encroachment of the thickened cortex upon the medullary portion of the bone (Fig. 2). The deformity is chiefly confined to the lateral and volar aspects of the phalanx. The changes appear to be the result of continuous soft-tissue pressure, and there appears to be some swelling of the soft tissues in this region. No clue as to the etiologic factor has been revealed by this study. All of the other bony structures appear normal."

*Operation.*—June 2, 1944: Under sodium pentothal anesthesia, the left hand was explored through an "S" incision, which began on the radial side of the index finger at the proximal interphalangeal joint and extended proximally to the level of the distal palmar flexion crease. Here it turned ulnarward across the palm, following the crease, and curved proximally with the thenar flexion crease about midway to the wrist. Care

was taken, in deepening the incision, to preserve the digital nerves and vessels which were crossed by the incision. This necessitated careful dissection and was much facilitated by the use of a bloodless field, produced by a pneumatic cuff tourniquet.

Wide exposure was obtained and after reflection of the skin and subcutaneous fat, the palmar fascia was seen to be thinned-out and elevated by a lobulated, yellowish mass in which were seen blotches of purplish tissue. One or two of these areas seemed to form lacunae or cysts, filled with venous blood. Clinically, the tumor resembled a xanthoma of tendon-sheath origin.

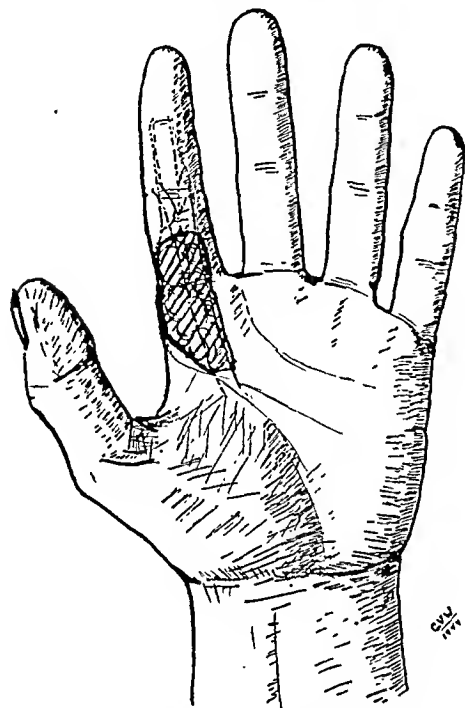


FIG. 3.—Diagram of left hand, showing extent of the tumor mass which is represented by the darkly-shaded area.

This tumor apparently arose from the flexor tendon sheath of the index finger, for it was intimately fixed to and mixed with the fibrous tissue of the sheath. Small vessels radiated from the tumor mass to the sheath, and the tumor appeared to be attached to no other structures. It extended dorsally along the radial side of the proximal phalanx and underneath the digital extensor complex. It had caused some flattening and distortion of the underlying bone, but was not adherent to it. The extent of the tumor is shown in the diagram (Fig. 3).

The entire flexor tendon sheath was removed from its beginning in the palm to the midportion of the proximal phalanx, where the tumor ended. Sufficient sheath remained at this point to act as the necessary "pulley" for the flexor tendons. The tendons were found to be smooth and glistening. The remainder of the tumor slipped easily from its bed and no visible remnant of the tumor tissue was left.

The tourniquet was released, hemostasis was secured with fine silk ligatures, and the skin was closed with interrupted fine silk sutures. Pressure dressings were applied.

The wound was dressed seven days later. Healing had occurred per primam, and all sutures were removed. On the tenth postoperative day, motion was begun actively and full motion of the finger was rapidly restored.

On June 20, 1944, he was returned to the Orthopedic Service for completion of his convalescence, and was discharged to duty on July 20, 1944. At the time of discharge, he could make a tight fist without pain and had full range of motion of all joints of the index finger and hand.

**Pathologic Examination.**—Grossly, the specimen consisted of a plaque of subcutaneous connective tissue, measuring  $4 \times 2 \times 0.5$  cm., in which was embedded a semi-transparent membrane enclosing a partially cystic structure, which was spongy in consistency (Fig. 4). The encapsulated mass was about six millimeters in diameter, and contained an encapsulated blood clot about three millimeters in diameter. On sectioning, the blood clot was surrounded by spongioblastic tissue which, in turn, was surrounded by a delicate fibrous membrane.

Microscopically, the sections showed a portion of a fibrous capsule which varied in thickness and which extended imperfect trabeculae into a mass of vascular spaces lined by endothelium (Fig. 5). The larger vascular spaces were small, thin-walled veins. About these there were thin capillary-like channels interspersed with strands of endothelial cells. The structure was that of a benign capillary hemangioma of the tendon sheath.



FIG. 4.—Gross appearance of the tumor, showing its lobulated, mottled appearance, with cystic, spongy areas of varying color and density.

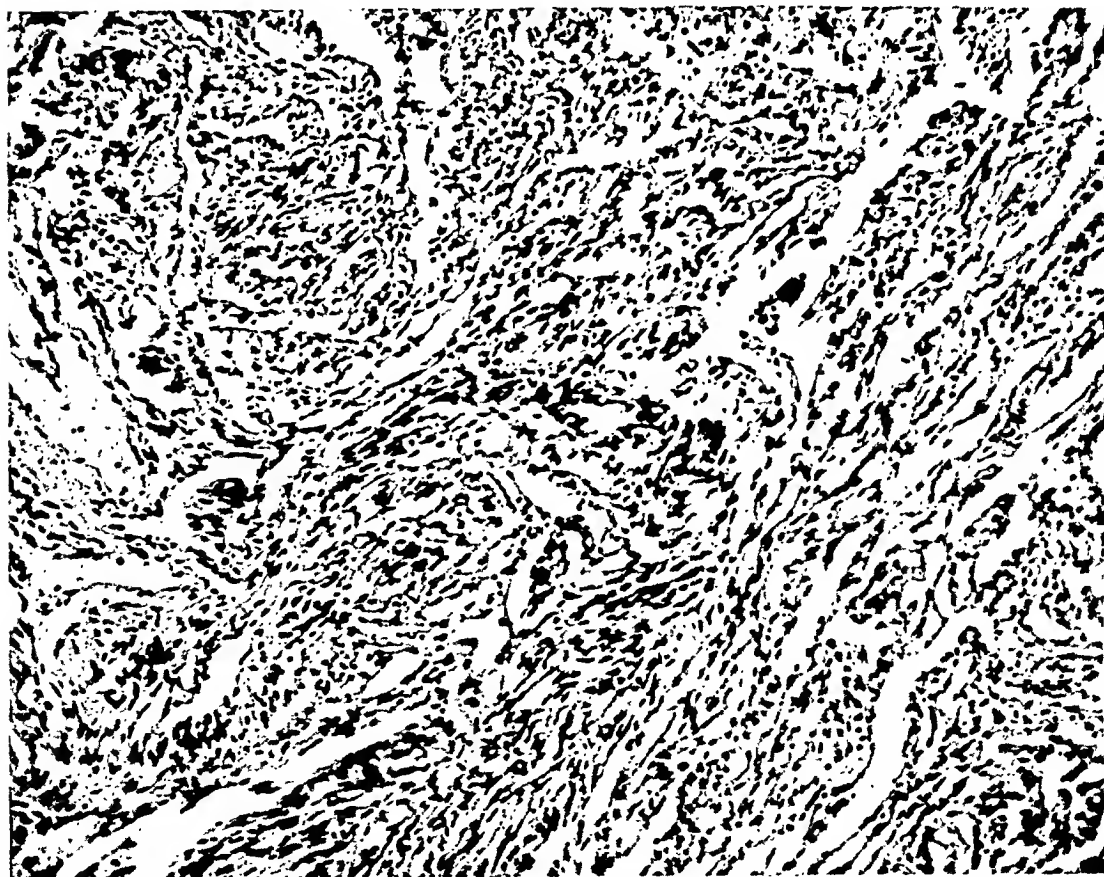


FIG. 5.—Microscopic appearance of tumor, showing ramifying endothelial-lined channels, loose fibrous stroma and strands of endothelial cells, which characterize a benign capillary hemangioma.

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*A request to Director Byrnes that the American Surgical Association be allowed to hold its meeting in May was politely but firmly refused. The Council has decided that the papers prepared for this meeting be published as a unit, without discussion, as proceedings of the Association.*

*William Darrach  
President*

## THE PROBLEM OF PORTAL HYPERTENSION, IN RELATION TO THE HEPATOSPLENOPATHIES\*

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IT MAY BE PERTINENT, in introducing the topic of this discussion, to say a few words about our interest and experience in the study of portal hypertension. Some 17 years ago, when the College of Physicians and Surgeons of Columbia University and the Presbyterian Hospital moved to their new common site, a group of physicians, surgeons and pathologists organized one of the several combined clinics. This soon acquired the name of the Spleen Clinic. Its purpose is to study patients with splenopathies before, during and after whatever treatment is decided upon by agreement of the group. The essential feature of this combined clinic is the laboratory, where all the blood studies and other tests are done by the same expert technicians on the patients, whether as out-patients, in-patients, or in follow-up visits. These patients are referred to the Spleen Clinic from the Vanderbilt Clinic, the Out-patient Department of the Columbia-Presbyterian Medical Center, and by other physicians; and after study and treatment they are returned to the referring physician with the request to have the patients return to the Spleen Clinic for indefinite follow-up studies<sup>1</sup> (Fig. 1).

As a result, there have been studied not only patients with splenopathies but many with disorders of the hematopoietic system and combined diseases of the liver and spleen. Table I is a summary of the splenopathies and the hepatosplenopathies that have been studied and followed in this Clinic to March 15, 1945.

No one can work for any length of time in a clinic of this kind, with

\* The E. Starr Judd Lecture. Read at The Medical School, University of Minnesota, April 10, 1945.

This paper was to have been presented before the Annual Meeting of the American Surgical Association, May, 1945.



physicians, surgeons and pathologists having a common purpose, without acquiring valuable experience and developing an interest in the diagnosis, treatment and end-results of these lesions. A common language is spoken and there are no miracles among friends. Again, I would emphasize the importance of having the accurate hematologic and other laboratory studies done by the same group of experts throughout the study of these patients. before, during and after treatment.

#### THE PORTAL SYSTEM

There are many marked differences between the portal and systemic venous systems, both anatomically and physiologically. The portal venous

#### ORGANIZATION SPLEEN CLINIC COLUMBIA-PRESBYTERIAN MEDICAL CENTER N.Y.C.

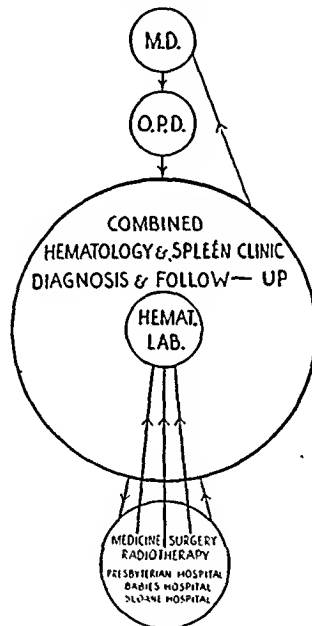


FIG. 1

system is interposed between two capillary beds. It drains the capillaries of the gastro-intestinal tract, the pancreas and the gallbladder, and the venous sinuses of the spleen; and empties into the capillary network, or sinusoids, of the liver. It has no valves. The portal vein carries about 75 per cent of the blood emptying into the liver. In this blood it carries nutrient material from the gastro-intestinal tract, and insulin from the pancreas, to be altered, detoxified and utilized by the liver, but it carries very little oxygen. For this the liver is dependent upon the hepatic artery which conveys the remaining 25 per cent of the blood entering the liver.

To understand the pathogenesis, the pathology, the diagnosis and the treatment of portal hypertension it is essential to review certain points in the anatomy and physiology of the circulation of the liver and the spleen. Unfortunately, there is still considerable controversy regarding some of these points; an endeavor is made to present as much of the new and accepted data as possible.

THE LIVER LOBULE IN RELATION  
TO THE PORTAL AND HEPATIC CIRCULATION

The mammalian liver is made up of small polygonal masses, each of which represents the architectural unit, or lobule, 0.7 to 2 mm. in diameter. In some mammals, as the pig, each lobule is completely surrounded by a layer of connective tissue, but in man these connective tissue partitions are poorly developed, resulting in less well-defined lobules. Furthermore, the liver lobule is determined by the arrangement of the blood vessels rather than by the duct system. The lobule is a polygonal prism, with five, six or seven sides, with the vertical diameter several times greater than the transverse. Running through the center of the lobule, in its long axis, is the central vein, while at the periphery are the branches of the portal vein with a lymphatic network, the branches of the hepatic artery and the interlobular bile ducts. The latter structures are enclosed in the connective tissue of Glisson's capsule.

Separating the central vein and the vessels in Glisson's capsule are the hepatic cells, arranged in cords with the sinusoids or capillaries running between the cords of cells and connecting the portal vein radicals and hepatic arterial terminals with the central vein. These central veins unite as intercalated veins to empty into collecting veins which, in turn, end in the hepatic veins to join the vena cava (Fig. 2).

THE RELATIONS OF THE BLOOD FLOW OF  
THE HEPATIC ARTERY AND THE PORTAL VEIN

One of the earliest and most significant studies on these two circulations was made by Gad<sup>2</sup> in 1873, who wrote a dissertation based on experimental work, in which he concluded that the arterial circulation in the liver performed the dual function of bringing oxygenated blood to the liver and of mechanically controlling the portal flow. He also suggested an aspirating action of the arterial on the portal current as the former passed by the openings of the latter, joining with them at an acute angle. He demonstrated that a current through the arteries with increased pressure retarded the portal flow.

In 1907, Herrick<sup>3</sup> published his studies on the causes of increased portal pressure in portal cirrhosis. He perfused normal livers and cirrhotic livers through the hepatic artery and the portal vein, noting the effect of the volume flow, one on the other, at increasing pressures. He pointed out that in the normal liver there is:

1. In the portal vein a large volume circulation with a low pressure.
2. In the hepatic artery a small volume circulation with a high pressure.
3. A common channel of exit, the hepatic vein, for fluid entering by these two circulations.
4. A freely expansible tissue framework.
5. Two methods by which the entering circulations may influence each other, *i.e.*, by direct communication or by lateral pressure.
6. A vasomotor mechanism to both sets of vessels.

7. An equalization of these pressures at the junction of the interlobular and intralobular venules of the liver lobules which takes place through the communications between the veins coming from the capillaries, bringing arterial blood and the portal venules.

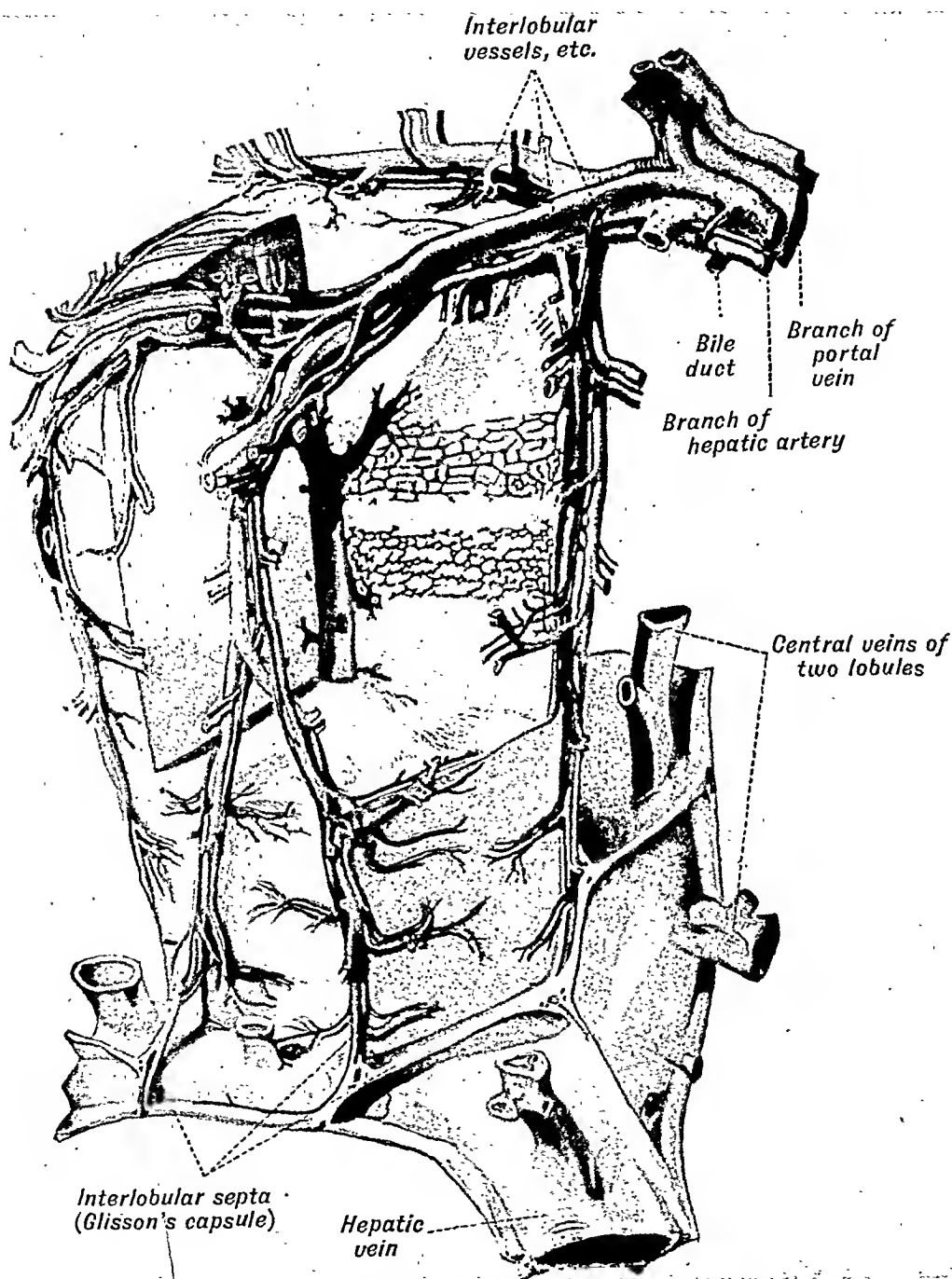


FIG. 2.—Lobule of the liver of a pig. Wax reconstruction by Vierling. A portion of the lobule is cut away to show the bile capillaries and sinusoids.  $\times 400$ . After Braus. (From Maximow's "Textbook of Histology," 4th edition. Philadelphia, W. B. Saunders Co.)

In the normal liver Herrick found that the rise in portal pressure was 1 mm. for every 40 mm. of arterial pressure; whereas in the cirrhotic liver it was 1 mm. for every 6 mm. of arterial pressure. It was found that arterial

rise in pressure did not affect the portal pressure in normal livers until it had passed the 100 mm. mark. In cirrhotic livers the effect on the portal pressure was evident at 30 mm. of arterial pressure.

McIndoe,<sup>15</sup> in his studies of the vascular bed of cirrhotic livers, found that a large part of the fluid perfused through the portal vein escaped through the collaterals, and that 13 per cent was the largest amount recovered from the hepatic vein, as compared to 100 per cent in the normal liver. On the other hand, he found that a much greater proportion of fluid, perfused through the hepatic artery, in a cirrhotic liver, passes out through the hepatic vein. He was unable to duplicate Herrick's observations that the high pressure in the hepatic artery was responsible for increasing the portal pressure.

In advanced cases of portal cirrhosis with the portal blood passing through established collaterals the shunt is able to carry a certain load, but with increased portal pressure rupture of the collaterals may take place. In such cases the hepatic artery is conveying most of the portal blood to the parenchyma of the liver.

As the combination of increasing interlobular fibrosis with degeneration and regeneration of liver cells slowly progresses, there is a gradual shutting off of portal blood from the hepatic cells. When the fibrosis increases to the point of shutting off the arterial supply parenchymal insufficiency develops. McIndoe points out that the duration of the period from the time of complete diversion of portal blood into collateral channels to the obliteration of the persisting arterial supply to the remaining liver cells is longer or shorter according to the rate of sclerosis of the intrahepatic vascular bed and the varying degree of involvement of the two circuits. This explains the variable periods of hemorrhage and of survival in cirrhotic patients.

McIndoe's analysis of the obstructive factor in cirrhotic livers questions the conclusions of Herrick in his perfusion experiments and throws new light on the rôle of the collateral channels in intrahepatic portal bed block. This is an important field for further investigation with new methods of study in the living animal with experimentally produced cirrhosis.

#### THE VASCULAR BED OF THE SPLEEN

The following discussion is abstracted from studies made in our laboratory<sup>4, 5</sup>:

Following Malpighi's<sup>6</sup> classic description of the anatomy of the mammalian spleen, in 1666, there has been a recurrent controversy among anatomists regarding the histology of the vascular bed of that organ. Proponents of an open circulation claimed that there was no continuity between the terminal arterioles and the venous sinuses, but that the splenic pulp spaces provide the only link between the arterial and venous radicals. Equally emphatic in their opposing claims have been those who maintained that the arterioles emptied directly into the venous sinuses and that the vascular bed was a closed system. Modern opinion rather favors a combined type of circulation

in the mammalian spleen, that is, an open component in the vascular bed which permits the flooding of the splenic pulp spaces with whole blood but with additional pathways available, by means of which the extravascular detour of the pulp spaces may be short-circuited by direct communications between the arterioles and the venous sinuses. Whether these arteriovenous connections of which it is composed are structurally intact vascular tubes or whether their appearance may be accounted for on a purely functional basis, such as an alteration in the porosity of the pulp caused by contraction of the splenic musculature, is considered to be an open question.

The reasons for this three-sided debate have been the difficulty of interpreting the intricate patterns of the spleen as seen in microscopic sections stained by different methods, and the varying results obtained by the several technics of injecting the vascular bed of the spleen both by artery and by vein.

In 1931, McNee<sup>7</sup> reported that "in the direct observations of the thin edge of a mouse's spleen, examined with a dissecting microscope and very powerful light, erythrocytes could be seen lying stationary in the pulp while blood was pumping freely through the adjacent arterioles into sinuses and then emerging by the veins." No one made use of this valuable suggestion in method until Knisely,<sup>8</sup> in 1934 and 1936, working in the Hull Laboratory, in the University of Chicago, published his studies on transilluminated living spleens. He described the finest structural and functional details of the vascular bed; and his account of them was expressed in no uncertain terms. His conclusion that the "unstimulated splenic vascular system of mice, rats and cats consists of a system of preformed, interconnected lined channels," normally intact and permitting the egress of only the fluid content of the blood, presented the most convincing argument in favor of the hypothesis of the closed circulatory mechanism in the spleen. He maintained that trauma incidental to manipulation, injection and fixation of the spleen had been responsible for the antagonistic studies of histologists in this field.

Knisely's positive description of the visualized functioning circulation in the spleen and his graphic schematic drawings of the venous sinuses in what he termed the three phases of filling, concentrating and emptying of red blood cells, with sphincters at the entrance and exit of the sinuses, were so convincing that several writers on the subject of splenic circulation have recently accepted his claims without question. Von Herrath,<sup>9</sup> in his paper published in 1938, speaks of the "hematocrit function" of the venous sinuses as demonstrated by Knisely. But no one, until we began this study, had repeated Knisely's observations or corroborated or questioned his conclusions.

Because many of the problems in the pathology and clinical manifestations of the splenopathies depend upon a knowledge of the exact mechanism of the circulation in the spleen, the members of the Spleen Clinic at the Columbia-Presbyterian Medical Center were especially interested in Knisely's papers.<sup>8</sup> We visited the Hull Laboratory on two occasions and later sent one of our Surgical Residents, Dr. David W. MacKenzie, Jr., for a period of

four months to study with Dr. Knisely. He most kindly gave Dr. MacKenzie every opportunity, and on his return to our laboratory the apparatus and method were set-up for studying the transilluminated spleen.

Before studying abnormal spleens it was essential for us to become thoroughly familiar with the circulation in the normal spleen. It had become apparent to Doctor MacKenzie that two fundamental faults in Knisely's technic made a continuous uninterrupted study of vascular fields impossible: The first, and most misleading, was the constantly moving visual field caused by the respiratory movements transmitted to the spleen under the microscope;

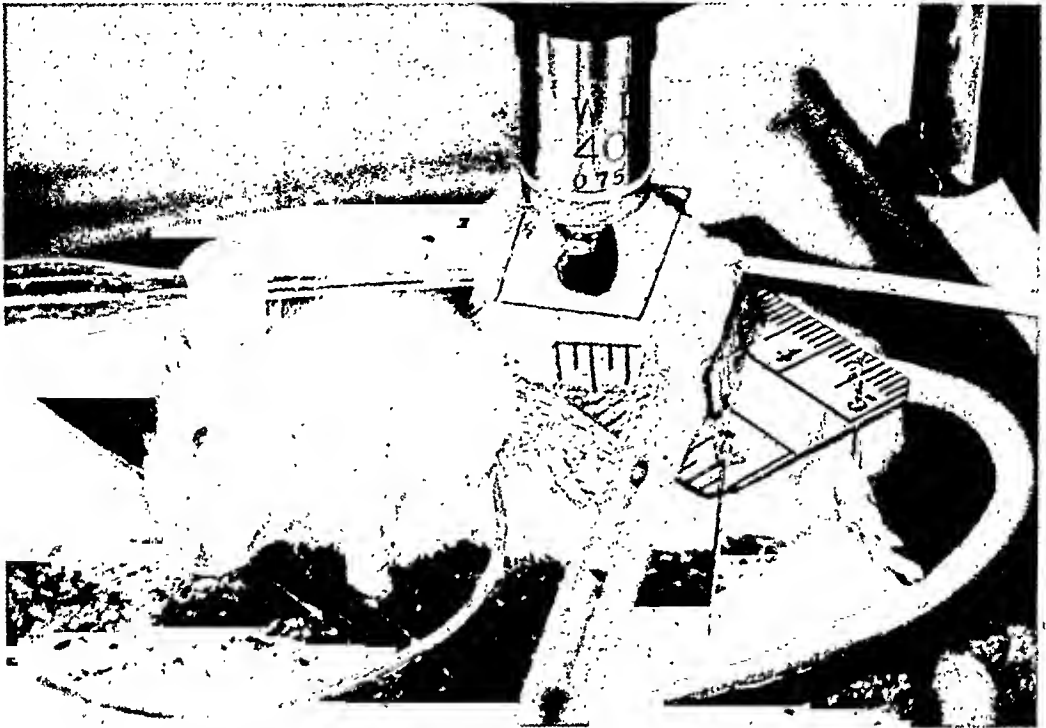


FIG. 3.—Transillumination apparatus arranged for observation of an exteriorized mouse spleen.

Hollow-tipped, fused quartz, illuminating rod enters chamber from left; immersion fluid delivery tube from right; and thermometer from foreground. Anesthesia fluid is being conveyed to this animal's left pectoral region. Light from illuminator tip is directed upward, through spleen substance, into water-immersion objective.

(From MacKenzie, D. W., Jr., Whipple, A. O. and Wintersteiner, M. P.: Studies on the Microscopic Anatomy and Physiology of Living Transilluminated Mammalian Spleens. *Amer. Jr. Anat.*, v. 68, No. 3, May, 1941.)

and the second was the frequent displacement of the spleen with the movements of the animal when the sodium amytal anesthesia was repeated by hypodermic injection. By devising a celluloid supporting table for the spleen and by using a continuous clysis of sodium amytal solution these two causes of a shifting microscopic field were eliminated, and it became possible, for the first time, to observe areas of the vascular bed in the immobilized organ without any shift in the visual field over uninterrupted periods of several hours. Before this was done, the necessity of filling in gaps between the views of the vascular bed we feel was the cause of fundamentally wrong observations and conclusions (Fig. 3).

We regret, therefore, that we were unable to corroborate many of Knisely's findings and were compelled, as a result of a year of study, to differ

positively from him in his conclusions that the circulation is a closed circulation and in the three phasic functions he attributes to the venous sinuses. Our observations were made by at least three, and sometimes more, members of the Spleen Clinic and the anatomic components or structures of the vascular bed have been recorded by camera lucida drawings of the functioning fields studied by us over periods of one or more hours in the living trans-illuminated spleen of mice, rats, kittens and guinea-pigs.

I wish to say that by far the major part of this study of the vascular bed of the spleen, the improved method and technics, the continuous observations and the drawings, both free hand and camera lucida, were made by Doctor MacKenzie and by his able assistant, Mrs. Wintersteiner. The detailed report of this study by MacKenzie, Whipple and Wintersteiner<sup>4</sup> appeared in the *American Journal of Anatomy*, 68, No. 3, 397-454, 1941.

The storm center in the controversy over open or closed circulation in the spleen has had to do with the question as to whether the arterial capillary terminates freely in the reticular meshes of the pulp spaces or directly into the venous sinuses. This question must be answered positively if certain essential points regarding the pathogenesis of many of the splenopathies are to be settled.

It is our definite conviction from our studies in the living spleen, which are in agreement with the conclusions of Mall,<sup>10</sup> Robinson,<sup>11</sup> Foot,<sup>12</sup> and Klemperer,<sup>13</sup> among others, from injected spleens and from microscopic sections, that the splenic pulp spaces provide the one and only link between the arterial and venous systems in the mammalian spleen. Individual pulp spaces are the most variable structures that we have observed in the spleen. For the most part they are tortuous, utterly irregular and inconstant channels, lined by fixed and wandering cells and by reticulum. They constitute a plexiform, three dimensional system of channels intimately connected with one another by actual or potential passages, fully adequate to transmit the cells as well as the fluid of the blood. The average width of the pulp spaces in the normal relaxed spleen of the mouse is six microns, but the diameter of a dilated pulp space has been measured to 16 microns. A collapsed or compressed space may have no visible lumen. On the arterial side of this fibrocellular sponge the pulp spaces communicate with the arterial capillary ampullae, or ampullae of Thoma. On the venous side, the spaces converge upon the stigmata, or free openings, of the venous sinuses and intralobular veins. Camera lucida drawings of this intermediary zone and of the pulp connections with arterial and venous systems are shown in Figures 4-7, and are in agreement with the semidiagrammatic drawing of the intermediary circulation in the human spleen (Fig. 8), as represented by Klemperer.<sup>13</sup>

Bear in mind this anatomy of the intermediary circulation in considering the pathology of chronic portal bed obstruction. The most characteristic feature in the microscopic sections of these splenomegalies is the widening and distention of the venous sinuses with a widening of the stomata resulting in a compression of the splenic pulp spaces. In addition, there is an hyperplasia

of the cytoplasmic reticulum. The back pressure in the venous sinuses, transmitted by the hypertension in the veins, causes the distention of the venous sinuses and the narrowing of the pulp spaces. This makes it more difficult for the blood to pass from the arterial capillaries into the pulp spaces. This results in hemorrhages about the trabecular arteries and at the periphery of the follicles, with a later development of nodular areas of fibrosis—the typical fibro-adenia described by Banti.

This partial exclusion of the splenic pulp from active circulation results in a gradual atrophy of the reticulum with connective tissue replacement and a fibrous spleen.

FIG. 4

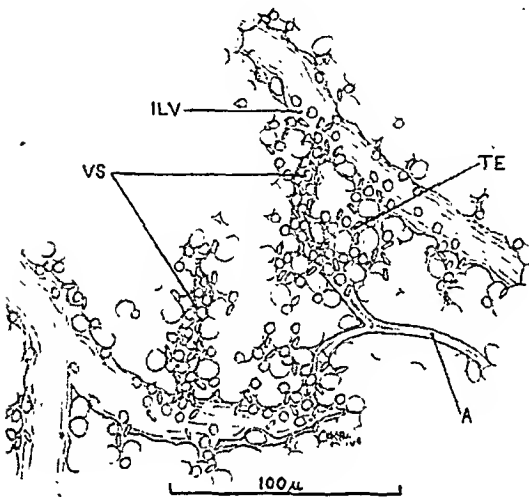


FIG. 5

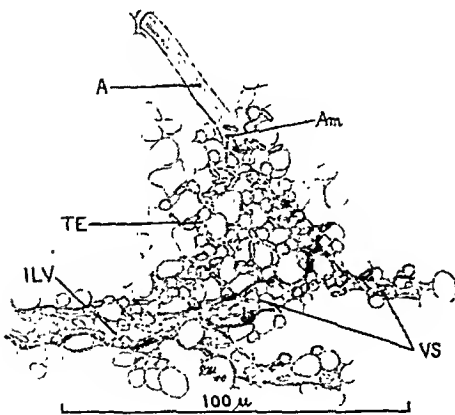
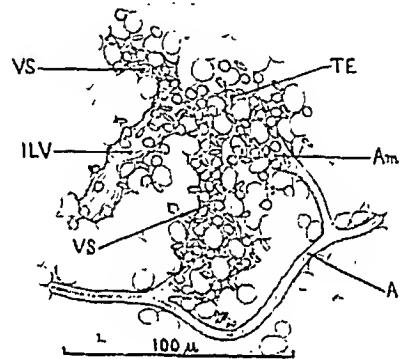


FIG. 6

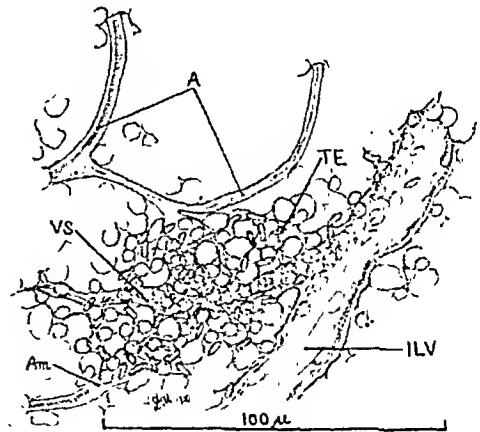


FIG. 7

FIGS. 4-7.—Intermediary circulation in transilluminated mouse spleens. Arterial capillaries, A, are shown to communicate via anapillary dilatations, Am, with swamp-like pulp zones, through which erythrocytes trickle onward, TE, into venous sinuses, VS, and intralobular veins, ILV.

Camera-lucida drawings. Lens magnification of Figures 4 and 5, 400; of Figures 6 and 7, 600. (From MacKenzie, D. W., Jr., Whipple, A. O. and Wintersteiner, M. P.: Studies on the Microscopic Anatomy and Physiology of Living Transilluminated Mammalian Spleens. *Amer. Jr. Anat.* v. 68, No. 3, May, 1941.)

#### OBSTRUCTIVE FACTORS

The amount of portal bed obstruction, the type and the site of obstruction, are all variable factors in individual patients with portal hypertension.



It is the discovery in the individual patient of these factors and their analysis that very largely determines the diagnosis, treatment and prognosis.

These patients with portal hypertension may be divided into two main groups: Group I. those having intrahepatic portal block; and Group II. those having extrahepatic portal block.

In the first group the cirrheses, especially of the portal or Laennec type,

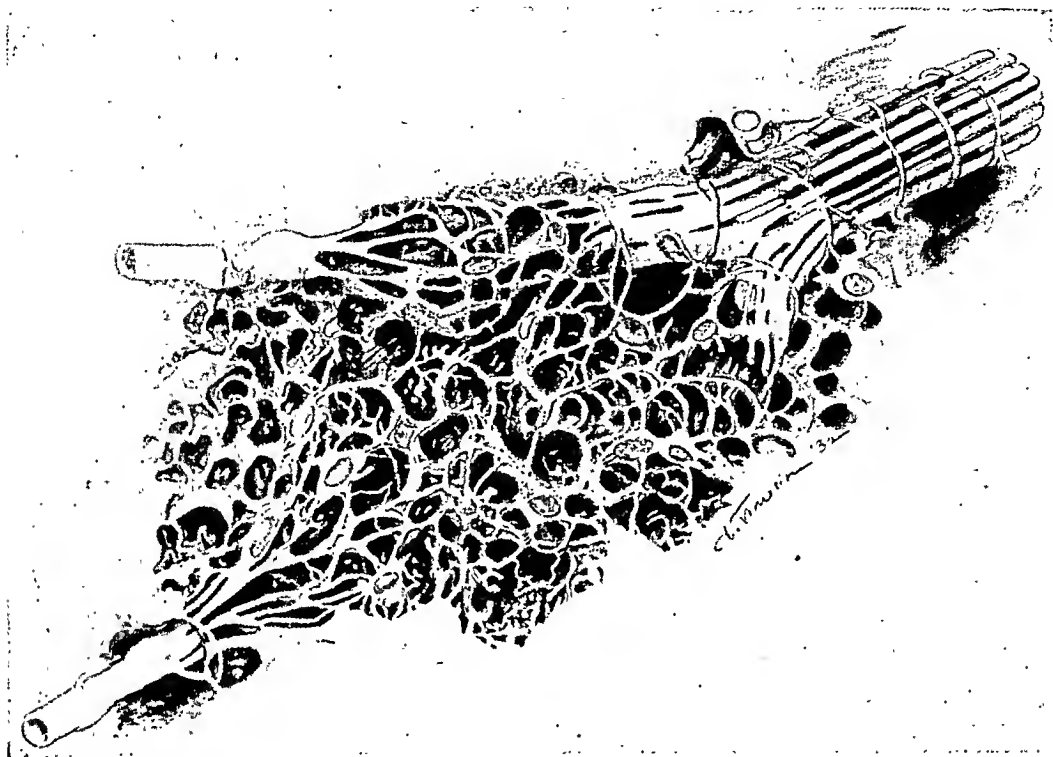


FIG. 8.—Semidiagrammatic drawing of intermediary circulation of human spleen.

This drawing represents author's concept of architecture of reticulum and its relation to finest blood channels. Although it is not an actual reconstruction of serial sections, all structural details which are depicted in three dimensions have been observed histologically. For technical reasons, reticular fibers have not been drawn in different color but as ridges upon cytoplasmic syncytium.

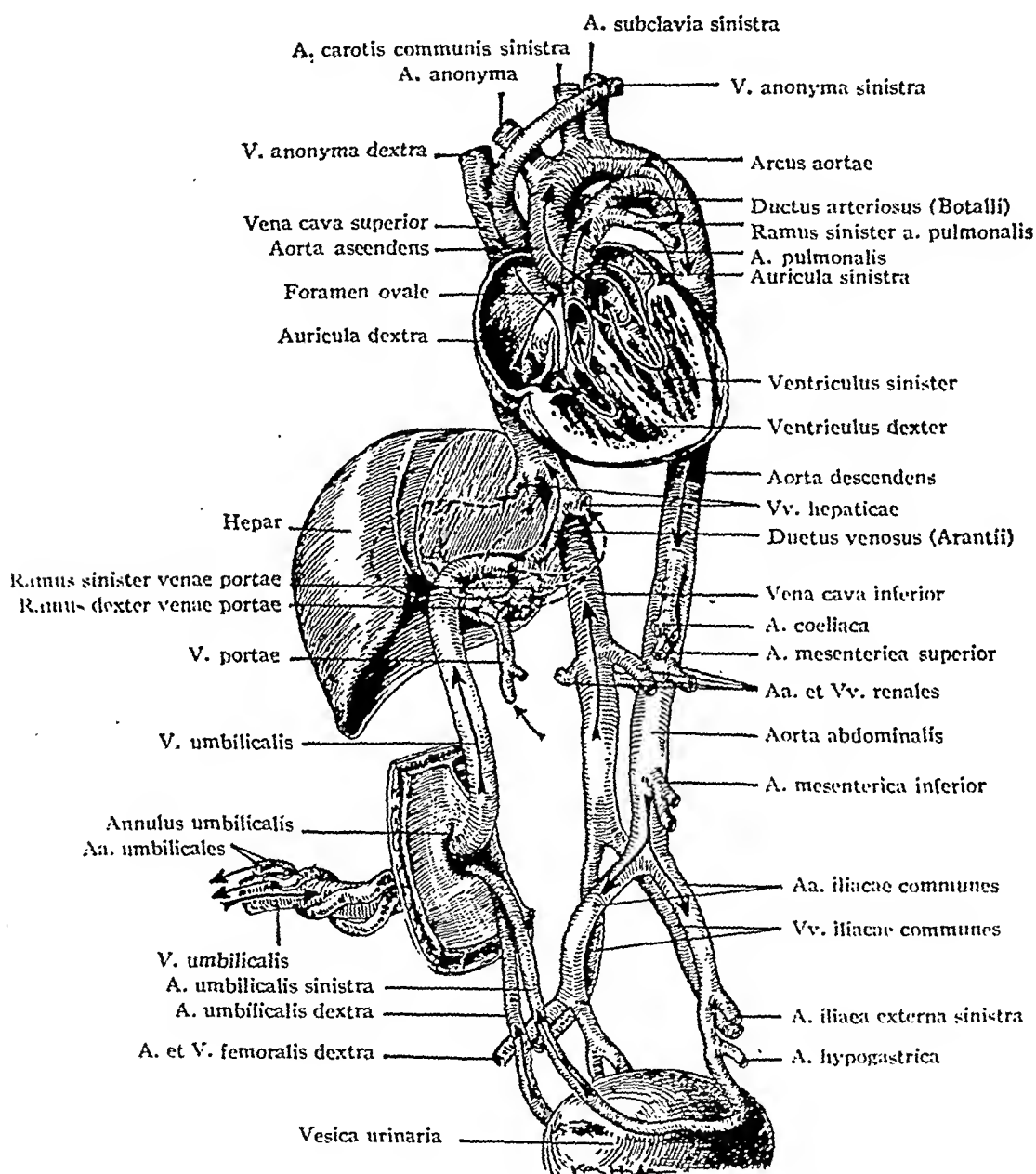
(From Klemperer, P.: Chapter on the spleen in Downey's "Handbook of Hematology." Paul B. Hoeber, New York, 1938, p. 1633. This figure is reproduced by kind permission of the publisher, Mr. Paul B. Hoeber.)

are associated with portal block. As pointed out by Herrick<sup>3</sup> in his perfusion studies, there is a great difference between the ratios of the increase in portal vein and hepatic artery pressures of normal and cirrhotic livers, *i.e.*, 1 mm./40 mm., and 1 mm./6 mm. This mutual influence between the portal and arterial pressures within the liver provides an important explanation for the rise of portal pressure in portal cirrhosis and also explains the variability of portal hypertension in the cirrheses and the presence or absence of gastrointestinal hemorrhage, as a measure of portal hypertension.

The degree of portal hypertension varies in the different types of cirrhosis and in the patients with the same type of cirrhosis and varies in the same individual with cirrhosis at different times. Thus, we find some patients with portal cirrhosis without a history of gastro-intestinal hemorrhage and with no splenomegaly, others have repeated hematemeses and enlarged spleens with marked engorgement of collateral veins.

## PORTAL HYPERTENSION

Group II. *Extrahepatic Portal Block*.—There are two types of obstruction seen in chronic occlusion of the portal vein and its main tributaries. The first is a replacement of the vein or its main tributaries with fibrous tissue or scar tissue with little or no canalization. The second is a transformation of the portal vein or its main tributaries or the enveloping tissue into a



From Callander's Surgical Anatomy  
Philadelphia, W. B. Saunders Co.

FIG. 9.—Diagram of the fetal circulation about the time of birth.

cavernomatous mass of small tortuous vessels, a process spoken of as cavernomatous transformation of the portal vein.

In the first type of fibrous replacement there are two causative factors. The most common is an organization into scar tissue of a thrombosis of the portal vein or of a main tributary. The thrombosis may be the result of inflammation, trauma, or pressure from without by inflammatory or

neoplastic tissue. The second causative factor is an extension into the left portal vein or proximal to it into the main portal vein of the obliterative fibrotic process that takes place at birth in the umbilical vein and ductus venosus as they empty into the left portal vein (Fig. 9). This type of obstruction is fortunately rare but is seen in young children that begin at an early age to show portal block with splenomegaly and a Banti syndrome. In these cases the liver shows no cirrhosis, but the portal vein obstruction may be partial or complete, and the portal vein may show either fibrosis or partial canalization. The collateral circulation is marked and gastro-intestinal hemorrhage with splenomegaly is a common finding.

The pathogenesis of cavernomatous transformation is not definitely known. By some it is considered to be the result of an organized thrombosis with recanalization; others consider it to be the result of telangiectatic granulation tissue; while still others consider it to be a congenital anomaly (against this is the fact that evidences of portal hypertension do not appear in some patients with this lesion until adult life). Other pathologists, especially Pick,<sup>14</sup> argue convincingly that this is a neoplastic lesion, an angioma or cavernoma of the hepatoduodenal ligament, inasmuch as in some cases the process extends far beyond the limits of the portal vein. It would seem logical that the etiology of this lesion is a variable one, caused in different individuals by one of the above factors.

#### COLLATERAL CIRCULATION IN PORTAL BLOCK

Under normal conditions the portal pressure varies from 8 to 13 mm. of mercury, or 60 to 104 mm. of water. With increase in pressure, and as portal block distends the portal radicals, potential veins connecting the portal system with the systemic begin to appear and enlarge to by-pass the portal blood.

These have been classified by Pick<sup>14</sup> into two groups—the “*hepatopetale*” and the “*hepatofugale*”. When the circulation through the liver is unobstructed and the block is limited to the portal vein the blood may be shunted to a limited extent through the *hepatopetale* collateral veins, the so-called accessory veins of Sappey, which pass through the peritoneal covering of the liver, or from the stomach and pass either into the stem of the portal vein or into the substance of the liver, the so-called deep cystic veins, the epiploic veins of the gastrohepatic omentum, the hepatocolic and the hepatorenal veins, the diaphragmatic veins and the veins of the suspensory ligament of the liver.

In lesions causing intrahepatic block the “*hepatofugale*” circulation shunts a variable amount of the blood from the gastro-intestinal tract and spleen around the liver. McIndoe<sup>15</sup> has classified the various parts of the “*hepatofugale*” collateral circulation into three groups on an embryologic basis:

## PORTAL HYPERTENSION

A. The veins located at the two sites of the gastro-intestinal tract where glandular epithelium unites with squamous epithelium, *i.e.*, at the cardia and at the anus. The veins at the cardia provide an outlet to the superior cava by way of the esophageal veins to the azygos system. The veins at the anus furnish an outlet to the inferior cava by way of the middle hemorrhoidal veins.

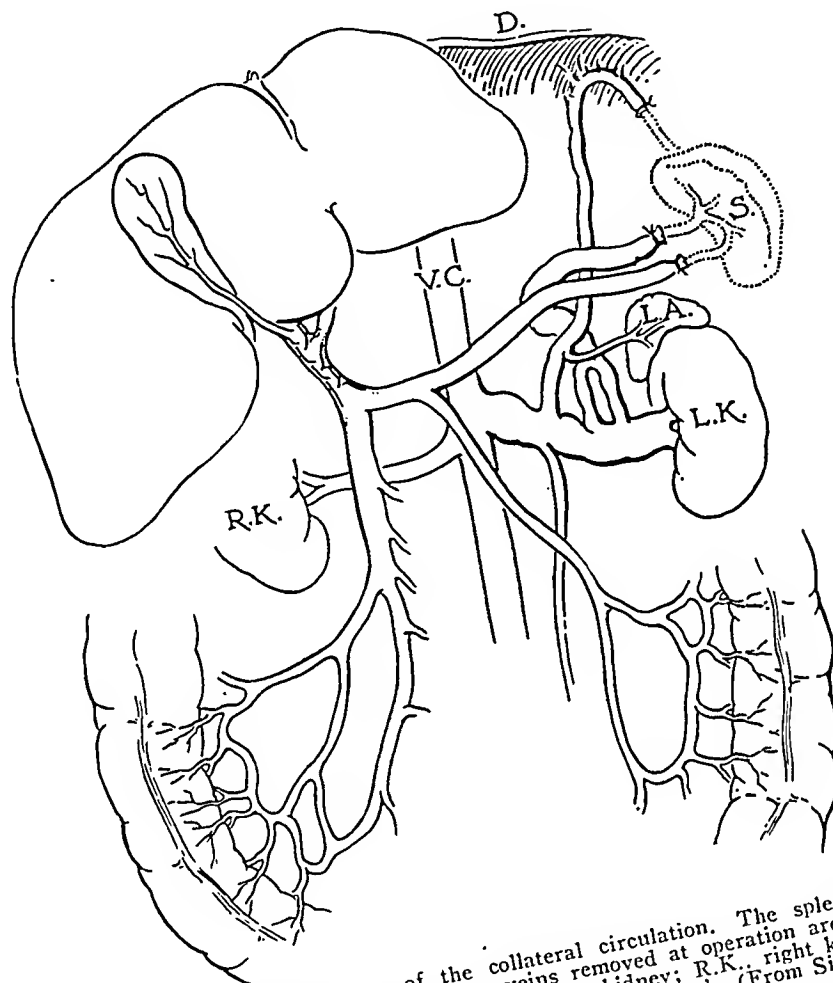


FIG. 10.—Diagram of the collateral circulation. The spleen (S) and the adjacent portions of the veins removed at operation are indicated by dotted lines. L.K. indicates left kidney; R.K., right kidney; V.C., vena cava inferior, and L.A., left adrenal gland. (From Simonds, *Archives of Surg.*, v. 33, 1936.)

B. The veins at the site of the obliterated fetal circulation, the para-umbilical veins in the round ligament of the liver.  
C. The veins found at the sites within the abdomen where the gastro-intestinal tract and its appendages, or the organs developed from it, become retroperitoneal developmentally, or adherent to the abdominal walls as a result of some pathologic process. These are sometimes spoken of as the veins of Retzius, and are well shown in the case reported by Simonds<sup>16</sup> (Fig. 10).

### EXPERIMENTAL PRODUCTION OF CHRONIC PORTAL BLOCK

This can be done successfully only by a gradual process of obstruction. A sudden closure of the portal vein, or one of its main tributaries, such as

the splenic, results in acute engorgement with either death of the organ, or organs, drained by the portal or an atrophy of the part drained by the obstruction.

Chronic intrahepatic block has been successfully done in our laboratory by Rousselot and Thompson<sup>17</sup> by the repeated injection of finely divided particles of silica into the splenic or portal veins. This, in a period of 12 to 18 months, results in a lesion almost identical with the severe portal



FIG. 11.—Gross specimen of experimental schistosomii cirrhosis with splenomegaly. Note size of the spleen to the left and dilated gastro-colic veins.

cirrhosis, splenomegaly and compensatory collateral circulation that is seen in victims of infestation with *Schistosoma mansoni*; for the fragmented ova of this parasite, passing from the portal tributaries to the liver produce the same kind of cirrhosis as do the particulate silica. Figure 11 is taken from an autopsy specimen in one of the dogs in Rousselot's and Thompson's experiments. These animals developed a typical Banti syndrome. Portal vein pressures in the animals showing cirrhosis and splenomegaly were recorded as high as 470 mm. of water. If allowed to live, some of these animals developed a massive ascites and showed tremendous esophageal varices.

Extrahepatic portal block is more difficult to produce experimentally.

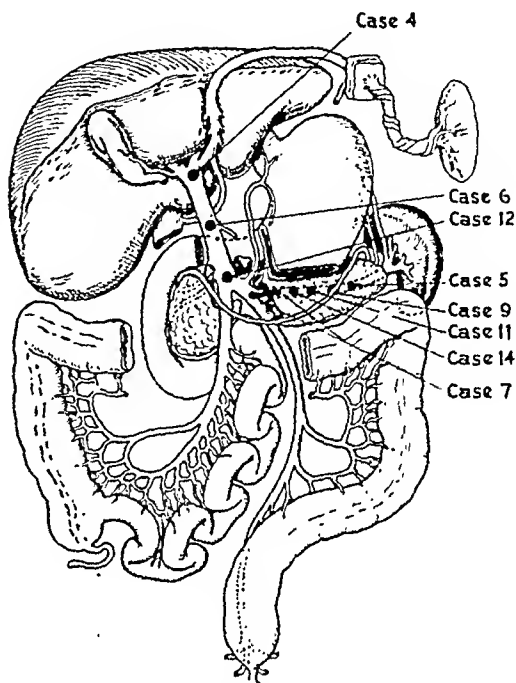
The most successful chronic extrahepatic obstruction in our laboratory was accomplished by Rousselot and Rennie,<sup>18</sup> using cellophane bands placed around the portal or splenic veins, without shutting off the flow of the vein. The gradual production of dense scar tissue around the cellophane bands resulted in a chronic portal obstruction in about half of the animals.

#### THE SYNDROME OF PORTAL BED BLOCK

In many of the patients, and in experimental animals, portal bed block produces a fairly typical syndrome. Certainly, this is true of the cases showing a splenomegaly whether the block is intra- or extrahepatic. This syndrome consists of a variable secondary anemia, a leukopenia, a thrombocytopenia, a splenomegaly and a tendency to repeated severe gastrointestinal hemorrhage, most frequently associated with ruptured esophageal varices. The liver may be cirrhotic or may be normal, depending upon the site of the portal bed obstruction (Fig. 12). This syndrome is frequently spoken of as Banti's syndrome.

Banti,<sup>19</sup> in 1883, first called attention to this syndrome, and subsequently published a number of papers on the subject, maintaining that the hepatosplenopathy was caused by some unknown toxic agent that first caused the splenic enlargement and later produced a cirrhosis. He described this as a disease running a chronic course, progressing in three stages: (1) The anemic phase, with splenomegaly, asthenia and occasional gastro-intestinal hemorrhage; (2) the transitional stage, with oliguria, urobilinuria, hepatomegaly, brown discoloration of the skin and increasing gastro-intestinal bleeding; and (3) an ascitic stage, with atrophy of the liver, subicteric sclerae, hemorrhages from the mucous membranes and death from hemorrhage or liver insufficiency. He noted some of the hematologic findings, and described the pathology as present chiefly in the spleen and the liver, with almost constant findings in the splenic and portal veins. The pathognomonic lesion he described as a conspicuous thickening of the fibrillar reticulum around the central arteries of the malpighian corpuscles. "The fibro-adenic alterations in the follicle distinguish *morbus* Banti. Their absence rules out the disease."

In fairness to Banti, it must be said that the term Banti's syndrome has not been confined to the entity as described by him. On the other hand, so few cases of hepatosplenomegaly with the anemia, leukopenia and gastro-



Schematic drawing (after F. Paire-H. Lacaze-S. Dupret), indicating the sites of the "obstructive factor" in the cases designated

FIG. 12.—Sites of obstruction noted in cases from our clinic reported by Rousselot.

intestinal hemorrhages, as described by Banti, show the three-stage process of the disease that the term Banti's syndrome has replaced to a large extent the term Banti's disease. Inasmuch as Banti insisted that the fibro-adenia of the follicles was the one pathologic finding in the spleen essential to the diagnosis of *morbus* Banti, the finding of this fibro-adenia in cases of splenomegaly, not fulfilling the clinical criteria of the disease described by him, and in cases with normal liver histology but with portal bed obstruction, invalidates the term Banti's disease.

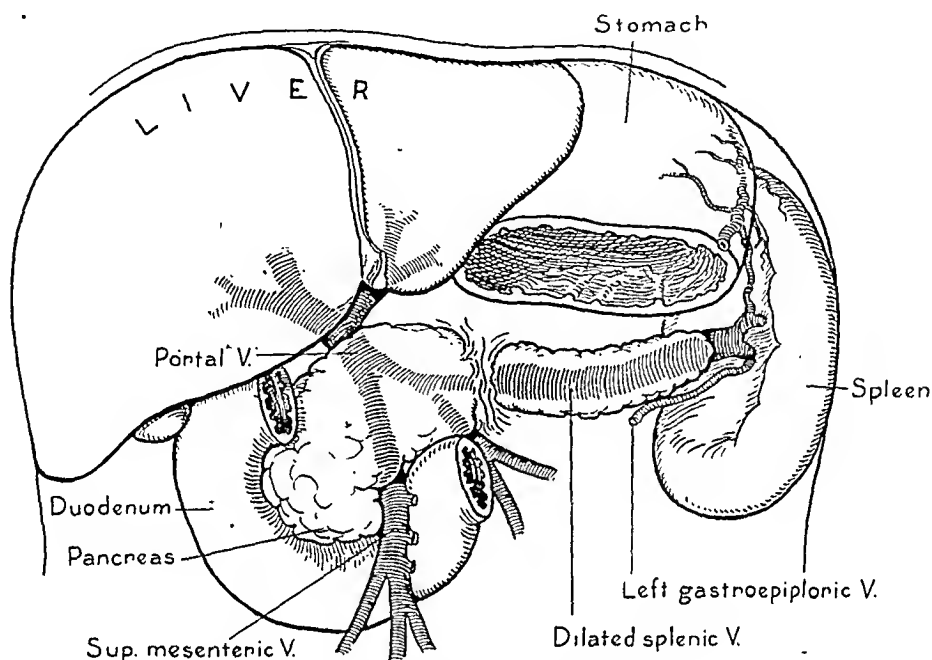


FIG. 13.—Findings in a case of splenomegaly following traumatic rupture of pancreas with splenic vein block.

Klemperer,<sup>13</sup> among others, advises that the term Banti's disease be abandoned. But the term Banti's syndrome, describing, in general, the syndrome met with in portal bed block is in the literature to stay, although its use too often implies an acceptance of Banti's disease as an entity.

The members of our Spleen Clinic at the Columbia-Presbyterian Hospital have, for a number of years, been especially interested in this syndrome of splenomegaly with anemia, leukopenia and thrombocytopenia, associated with the development of increased collateral circulation between the portal and peripheral venous systems and characteristic histologic changes in the spleen. The patient who first demonstrated to us this syndrome in complete conflict with Banti's hypothesis was a young, vigorous policeman giving the following history: In 1928, in attempting to stop a runaway team he was pinned between an elevator pillar and the tongue of the wagon. This resulted in a rupture of the pancreas, for which he was operated upon at the Post-Graduate Hospital by Dr. John Erdman. A few months later he developed a pancreatic cyst which Doctor Erdman drained. At this time his spleen was not enlarged and his blood picture was normal. During the next three years

he gradually developed a splenomegaly and an anemia with a leukopenia and thrombocytopenia, and had two severe hematemeses. The clinical picture and diagnosis of Banti's syndrome was evident. In 1932 I removed his spleen, finding, at that operation, a very large spleen with an enormously dilated splenic vein, which entered dense scar tissue at the site of the injury to the pancreas, resulting in splenic vein obstruction and diffuse collateral circulation between the splenic vein and branches of the left gastric and left gastro-epiploic veins. The liver appeared normal in every respect. This

TABLE I  
SPLEEN CLINIC—PRESBYTERIAN HOSPITAL  
*Cases to March 15, 1945*

	Cases With Splenectomy	Cases Without Splenectomy	Total No of Cases
Abdominal Buerger's disease.....	1	8	9
Anemia:			
Aplastic.....	2	84	86
Cooley's.....	9	17	26
Sickle cell.....	2	22	24
Banti—Extrahepatic:			
Cavernomatous transformation.....	4	2	6
Compression.....	2	3	5
Sclerosis of portal veins.....	5	1	6
Thrombosis.....	3	3	6
Stenosis of portal veins.....	3	1	4
Banti—Intrahepatic:			
Cirrhosis.....	36	59	95
Cirrhosis schistosomal.....	14	3	17
Banti—Obstructive factor undetermined.....	26	9	35
Boeck's sarcoid.....	2	6	8
Cyst of spleen.....	1	..	1
Gaucher's disease.....	10	3	13
Hemolytic jaundice:			
Atypical.....	10	11	21
Typical.....	53	20	73
Hodgkin's disease.....	2	172	174
Leukemia—Chronic myeloid.....	1	152	153
Normal splenectomies.....	42	..	42
Osteosclerotic myelofibrosis.....	3	14	17
Polycythemia.....	1	108	109
Purpura:			
Atypical.....	10	82	92
Idiopathic thrombocytopenic.....	52	26	78
Sarcoma of spleen.....	10	7	17
Splenomegaly—Undetermined origin.....	12	60	72
Total.....	316	873	1,189

patient made an uneventful recovery and his blood values promptly returned to normal and remained so for the next nine years of his follow-up. He had no recurrence of hematemesis.

This finding of a normal liver on the right and a splenomegaly on the left with an obstructive factor between and the picture of Banti's syndrome initiated certain studies which have clarified our ideas regarding the pathogenesis of what we agree with Larrabee<sup>20</sup> should be called congestive splenomegaly.



Our Spleen Clinic studies on splenic vein pressures made at the time of splenectomy and compared with peripheral venous pressures were reported by the Spleen Clinic in 1937.<sup>21</sup> These showed an increase of two to five times splenic vein pressure over peripheral venous pressure in cases presenting Banti's syndrome. Table II shows the comparative readings in the different types of splenomegaly. It is our present concept that Banti's syndrome is

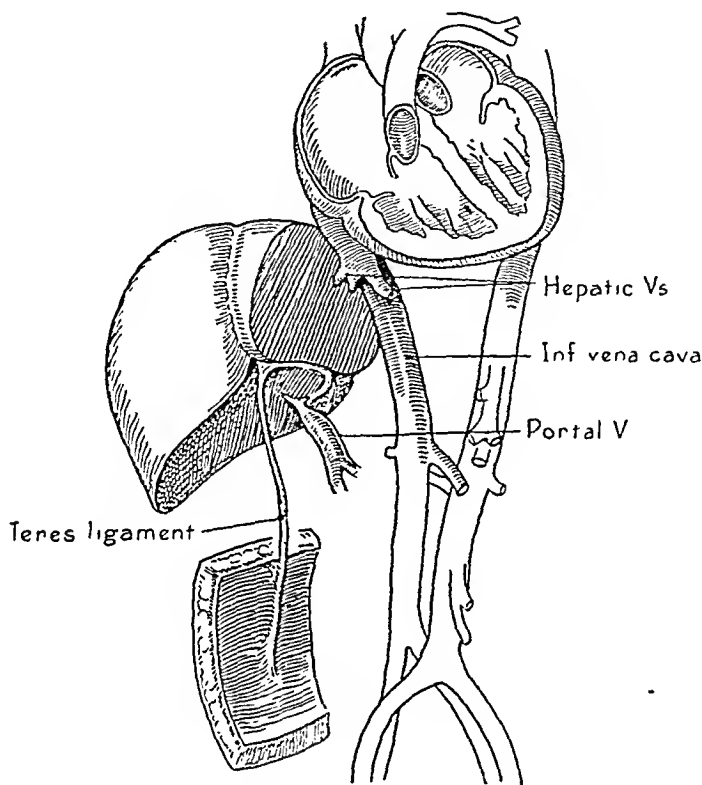


FIG. 14.—Autopsy findings in case of extrahepatic portal block following extension of obliterative process from the umbilical vein into the portal vein.

the result of mechanical obstruction to the flow of blood within the portal bed.

In the cirrhoses there is a variable amount of portal hypertension, determined by the amount of scar tissue in Glisson's capsule, the relation of the pressure in the hepatic artery to that in the portal vein and the extent of the hepato-fugal collateral circulation. For these reasons splenomegaly, gastrointestinal hemorrhage, leukopenia and thrombocytopenia are not always found in the cirrhoses. This syndrome is not characteristic of the biliary and cardiac cirrhoses.

On the other hand, in our experience, if the extrahepatic portal block, from whatever cause, is sufficient to produce a splenomegaly, Banti's syndrome is nearly always present, and a normal liver is usually found even in the cases of long standing, some of which we have followed for 10 to 20 years, and that because of recurrent esophageal hemorrhage have provided us with autopsy studies.

# PORTAL HYPERTENSION

H. J. Ward: G-W. First admission: March 17, 1926-May 27, 1926. Twenty-third and final admission: July 22, 1939. Died: July 26, 1939.

*Autopsy Report—Final Note:* A young man, age 18, who had been in the hospital 23 times for repeated hematemeses, which first occurred at the age of 2.5 years. A diagnosis of Banti's disease was made at the age of five, and was followed by splenectomy. He developed extensive esophageal varices and these were cauterized several times, but

TABLE II

## SPLenic VEIN PRESSURE IN THREE CASES OF BANTI'S SYNDROME ASSOCIATED WITH CHRONIC SCHISTOSOMIASIS

Case No.	Splenic Vein Pressure Mm. H <sub>2</sub> O	Simultaneous Arm Venous Pressure Mm. H <sub>2</sub> O
1. P. R.....	250	50
2. A. E.....	335	105
3. G. P.....	500	70

## SPLenic VEIN PRESSURE IN FIVE CASES OF BANTI'S SYNDROME ASSOCIATED WITH LAENNEC'S CIRRHOSIS

Case No.	Splenic Vein Pressure Mm. H <sub>2</sub> O	Simultaneous Arm Venous Pressure Mm. H <sub>2</sub> O
1. C. M.....	275	12
5. G. M.....	325	85
6. D. P.....	450	125
7. L. DeR.....	275	105
8. N. A.....	470	140

## SPLenic VEIN PRESSURE IN THREE CASES OF TYPICAL HEMOLYTIC JAUNDICE

Case No.	Splenic Vein Pressure Mm. H <sub>2</sub> O	Simultaneous Arm Venous Pressure Mm. H <sub>2</sub> O
9. R. B.....	105	80
10. N. B.....	125	130
11. W. U.....	120	85

intermittent bleeding persisted throughout his life. During the final few months a loud systolic murmur developed and the question of rheumatic endocarditis was raised. Terminally, his blood platelets fell sharply and he developed an hemiplegia which was thought possibly due to the formation of platelet thrombi.

Autopsy shows the cause for the splenomegaly and varices to reside in a greatly narrowed, trabeculated portal vein. Many collateral channels have been established. In some of these about the splenic vein as well as in the latter, and in the portal vein there is considerable phlebosclerosis. Hyaline thrombi are found in veins of the myocardium, kidneys, and rectum, and the right posterior cerebral artery is obstructed by a similar thrombus. The mitral valve bears large organizing vegetations, probably rheumatic in origin. The kidneys show what is probably an early intercapillary glomerulonephritis. There are also small foci of necrosis of tubular epithelium and beginning regeneration, the cause of which is unknown. Sections of the liver appear normal. There is no evidence of cirrhosis.

The pathogenesis of the portal vein lesion is open to discussion. It suggests cavernomatous transformation of a relatively simple type. An early, perhaps congenital, development of the lesion is indicated by the early onset of symptoms, and Doctor

Thompson suggests that the normal postnatal obliteration of the umbilical vein might conceivably extend into the portal trunk. The extensiveness of the collateral circulation, and the enlargement of the hepatic artery, are evidences of compensation in a growing individual.

#### THE DIAGNOSIS OF PORTAL HYPERTENSION

Patients with a portal hypertension great enough to cause an enlarged spleen usually present the leukopenia and thrombocytopenia and secondary anemia of Banti's syndrome. There may be no history of gross gastrointestinal hemorrhage. The differential diagnosis from other splenomegalies is largely determined by accurate hematologic studies.

The site of the portal block, as to whether it is intrahepatic or extrahepatic can usually be determined by certain liver function tests. If there is a high retention of bromsulphalein in the blood 30 minutes after intravenous injection, if the hippuric acid test is positive, if there is a reversal of the albumin-globulin ratio or if the cephalin flocculation test is positive, the presence of a cirrhosis with intrahepatic portal block is fairly certain. On the other hand, if these tests are negative it is safe to assume that the block is extrahepatic. But this does not necessarily determine the site of the extrahepatic block. In patients with normal liver function if there is a history of an antecedent pancreatitis or a severe trauma to the epigastrium the diagnosis of a splenic vein thrombosis is a valid one. In a young child with normal liver function tests, giving a history of hematemesis at an early age the diagnosis of portal vein occlusion as a result of continuation of the obliterative process in the umbilical vein and ductus venosus is a probable one.<sup>22</sup> The final determination of the site of the extrahepatic block in many patients can be made only at the autopsy table, for the dissection necessary to demonstrate such a block is neither safe nor feasible in the great majority of patients on the operating table. We have been unable to determine the site of the extrahepatic block at the time of splenectomy in more than half of our patients, although in our more recent operations we have demonstrated the block by diodrast venograms taken at the time of determining portal vein pressures with roentgenograms at the operating table.

#### THE TREATMENT OF PORTAL BED BLOCK

The therapy of the cirrheses not associated with portal hypertension does not come within the scope of our topic. It is the portal bed block, both intra- or extrahepatic, associated with Banti's syndrome that poses the problem to be considered in this discussion.

Three factors, the site of the block (Fig. 12), the degree of portal hypertension and the extent and competency of the collateral circulation determine the size of the spleen and the incidence of gastro-intestinal bleeding. The two latter components of the syndrome are the usual indications for attempted surgical therapy. In the past, three lines of surgical attack have been fol-

lowed—by splenectomy; by the establishment of collateral circulation with intra- or extraperitoneal omentopexy; and by ligation of the tributaries to esophageal varices. These will be considered separately.

The spleen carries a very large load of the portal blood, estimated at 40 per cent of the total. Splenectomy, especially if the spleen is as large as it usually is with Banti's syndrome, removes not only a large area of the portal bed, but shuts off many of the large collateral veins in the gastrolenal ligament that feed into the varices around the diaphragm, the cardia and the esophagus.

If the portal block is in the splenic vein the removal of the spleen results in a permanent cure, with the disappearance of the Banti syndrome. Unfortunately, this site, in the splenic vein, for portal bed block is not a common one. We have had only five such cases, but they were all cured, with no recurrence of hematemesis. But even with the block in the main portal vein splenectomy provides relief for a variable time because of the removal of a large area of portal bed and until the portal hypertension builds up again.

The establishment of an adequate collateral circulation by omentopexy: whether by the Talma-Morison procedure of placing the omentum in contact with an abraded or irritated surface of the liver or by suturing the omentum in contact with the split rectus muscle, the efficacy of omentopexy is questionable. In our experience, if the operation is done in the presence of a well-established collateral venous circulation in the abdominal wall, as evidenced by dilated superficial veins, or as shown by infra-red photographs, the results in a few cases are encouraging, but probably due to Nature's efforts rather than to the surgeon's.

Attempts to ligate the tributaries feeding into the veins of the cardia and esophageal varices have been very disappointing. Nor have the injection and coagulation methods to obliterate the esophageal varices been any better. At best, these procedures shut off one of the chief collaterals between the portal and systemic circuits and increase the portal hypertension. The large number of patients with portal vein block and Banti's syndrome whose spleens we have removed, but who continued to have recurrent gastro-intestinal hemorrhage, challenged the members of our Spleen Clinic to seek a more effective and permanent therapy.

Our efforts to anastomose branches of the mesenteric veins to the spermatic, the ovarian and the inferior cava by suture technic had failed. These suture anastomoses dealing with small veins are technically difficult and even with anticoagulants usually close by thrombosis. Attempts to make such shunts in the past have been reported by Gunn<sup>23</sup>—right ovarian to the portal; Villard and Tavernier<sup>24</sup>—ovarian to the superior mesenteric; and Meursing<sup>25</sup>—spermatic vein to the splenic, without success. Bogorts<sup>26</sup> anastomosed the superior mesenteric to the inferior cava and reported a good result. One

month later the spleen had decreased in size and ascites had disappeared. There was no later follow-up note.

✓ We had discussed the more extensive procedures for portacaval shunt based on the principle of the Eck fistula, but because of the difficulties of dealing with the engorged portal tributaries and the disadvantages of suture anastomosis, with the threat of thrombosis, we made no attempts to carry out such procedures until Blakemore, of our Surgical Staff, developed his endothelial-lined vitallium tube nonsuture technic for bridging large vessel defects. Blakemore and Lord<sup>27</sup> have recently described this technic, and have made a major contribution to vascular surgery. Before describing this technic as applied to the problem of portacaval shunting operations, it is pertinent to discuss the history of portacaval anastomosis both in experimental animals and in human cases.

Nikolai Vladimirovich Eck was a Russian physiologist, born in 1847. In 1877, he published his report on "The Ligature of the Portal Vein."<sup>28</sup> He developed the Eck fistula for the experimental study of diseases of the liver and the relation of the liver to metabolism. Eck suggested that a portacaval fistula might be used to sidetrack obstruction in the portal vein, but the procedure found no trial for many years, until Tansini,<sup>29</sup> in 1902, advocated it on the basis of his animal experiments.

Vidal,<sup>30</sup> of Angers, claimed to have done this operation for the first time upon a patient with portal obstruction in 1903. This patient lived 14 weeks, and died of a septic endophlebitis. De Martel<sup>31</sup> reported a patient upon whom he had done an Eck fistula in 1910. The patient succumbed shortly with anuria. Lenoir,<sup>32</sup> according to Rosenstein, carried out an end of portal to side of cava anastomosis, but the patient died of anuria. Rosenstein<sup>33</sup> presented a 60-year-old woman, before the 41st Congress of German Surgeons, upon whom he had done an Eck fistula for cirrhosis and ascites in 1911. She had been tapped repeatedly, and five months after the Eck fistula operation this patient required only an occasional paracentesis with much less ascites.

The Eck fistula has been carried out in experimental animals very many times. Probably no one has had so much experience with constructive analysis in the study of Eck fistula dogs as George H. Whipple. His recent report<sup>34</sup> on his study of Eck fistula animals is an amazing example of carefully analyzed data on the metabolism of hemoglobin and protein in normal and in depleted Eck fistula dogs. He has observed some of these animals for periods as long as eight years, maintained in apparent state of health. They appear normal in all respects, activity, appetite, digestion and weight, but occasionally they may show increased thirst, diuresis, a trace of jaundice or lack of appetite and vague intoxication, evidences of disturbed protein metabolism.

In a letter,<sup>35</sup> written to me recently, Dr. Whipple says that the Eck fistula in dogs consists of a large opening between the portal vein and vena cava, usually 12 mm. in long diameter. The portal vein is ligated and crushed

just as it enters the liver. All operations are checked at autopsy to show that the fistula actually was present during the period between operation and death. Unless the portal vein is ligated the side-to-side opening will promptly close. In this series, Dr. Whipple says the hepatic artery is adequate to support relatively normal clinical activity for many years. He states that he has no knowledge of observations on human Eck fistulae, and considers the operation in cases with portal hypertension an extraordinarily interesting field for protein metabolism studies. He predicts that, as in experimental animals, they will have periods of good and periods of poor protein production.

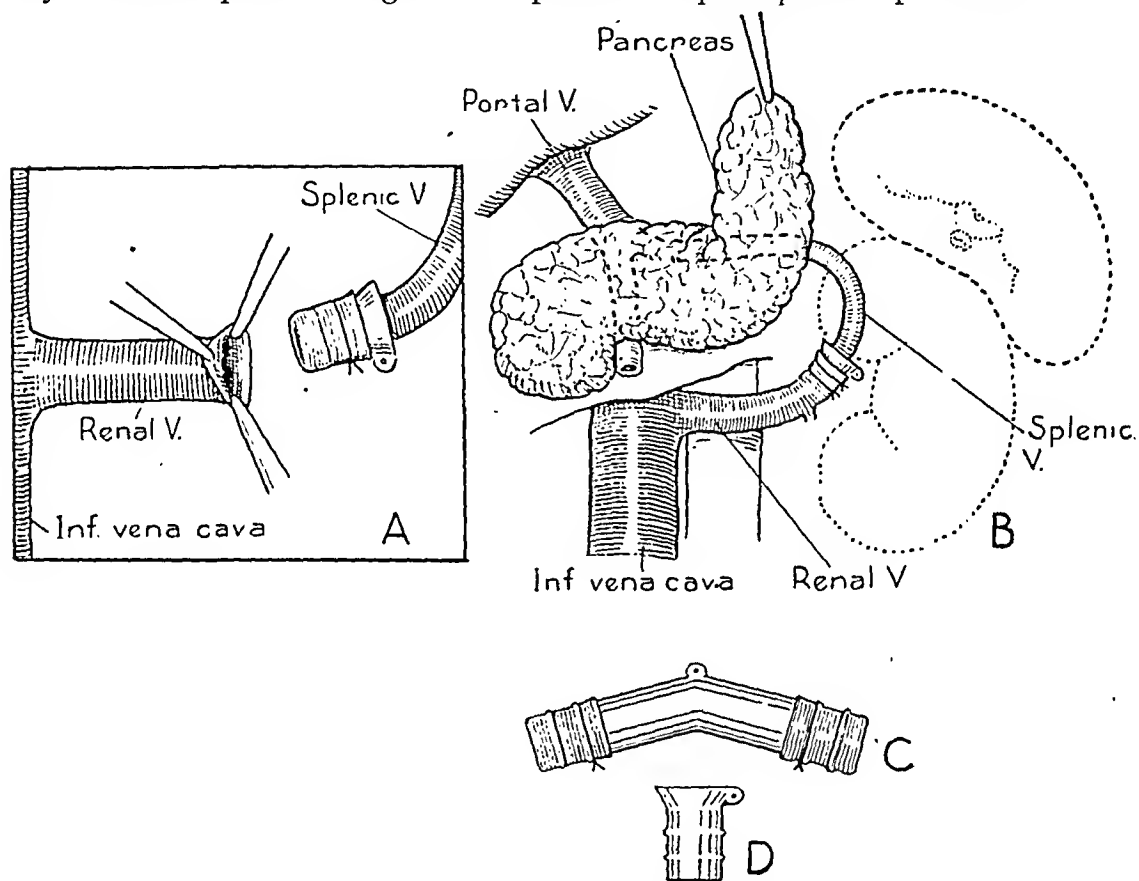


FIG. 15.—Showing technic employed in use of vitallium tubes in portacaval shunts.\*

Quierolo,<sup>36</sup> in 1893, carried out a procedure for an Eck fistula in 16 dogs which was never given adequate recognition. He everted the cut-end of the portal vein over a glass tube and introduced this into an opening in the inferior vena cava, below the renals, taking care not to have the ligature tying the everted portal enter the cava. Two of these animals lived six months after operation. We were not aware of Quierolo's work until we had completed portacaval shunts in six of our patients.

Blakemore had demonstrated, in a large number of animal experiments and in several clinical cases, that arteriovenous anastomosis, arterio-arterial anastomosis and vein graft anastomosis could be done successfully by his nonsuture method in blood vessels of the extremities. By everting the end

\* For details of this procedure see Figure 2 in article by Blakemore and Lord on page 479 of this issue of the ANNALS OF SURGERY,

of a vein or artery over the end of a short funnel-shaped vitallium tube, the endothelial surface can be introduced into the open end of another vein or artery to maintain blood flow, with avoidance of thrombosis because of intact endothelial lining. Or by using such tubes at either end of a vein graft vascular defects in arteries or veins can be effectually bridged (Figs. 15-16). Using this principle, Dr. Blakemore and I have carried out ten of these major procedures, five consisting of uniting the splenic vein and left renal veins, after

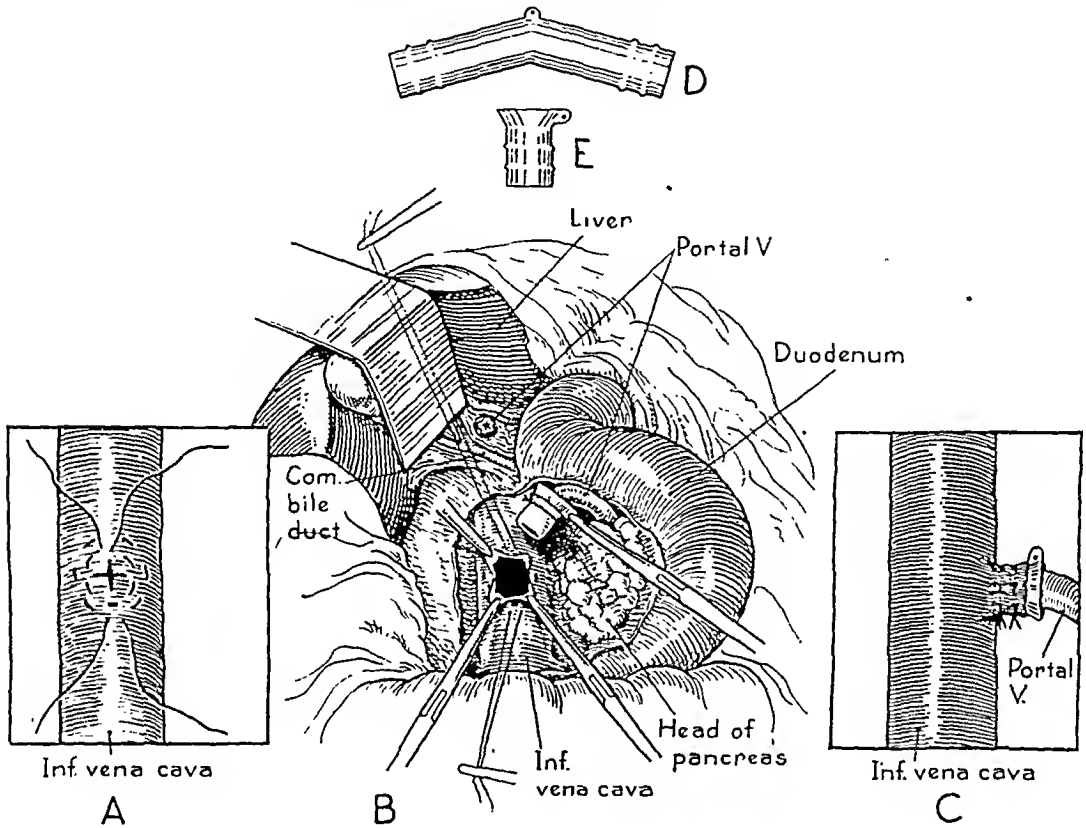


FIG. 16.—Showing technic employed in use of vitallium tubes in portacaval shunts.\*

removing the spleen and left kidney. In our last five patients we have anastomosed the portal vein to the inferior cava, end-to-side. All these patients have survived their operations.

These procedures are as yet purely experimental. They have been carried out in patients that had had repeated severe hemorrhages, and for whom conservative measures offered no hope. The results in five of these patients have shown such a marked improvement in their liver function tests and disappearance of ascites or hemorrhage that we have been encouraged to continue, with improved technic, our efforts to provide an adequate short-circuiting of portal blood by the nonsuture technic. These are difficult, trying operations in the presence of engorged portal radicals, and require the teamwork of surgeons experienced in upper abdominal and in the basic principles of blood vessel surgery. Present-day methods for preventing and com-

\* For details of this procedure see Figure 3 in article by Blakemore and Lord on page 481 of this issue of the ANNALS OF SURGERY.

bating shock; for improving compromised blood clotting mechanism and hypoproteinemia; together with the Blakemore nonsuture technic account for the fact that all ten of these patients survived the critical operative and post-operative period. It will require a follow-up period of three years, or more, to determine the value of these portacaval short-circuiting procedures. At least they represent a bold attempt to deal with the problem of portal hypertension in its life-threatening forms.

Four other splenorenal vein anastomoses for portal hypertension have recently been performed by Dr. Alfred Blalock,<sup>37</sup> who writes me that two of these patients have had a disappearance of ascites and are remarkably improved. On the other hand, he says his enthusiasm is somewhat curbed because the other two patients have died since operation from recurrent bleeding from esophageal varices. He thinks this may be due to occlusion of the anastomosis as a result of the attendant trauma at time of the operation.

With the present improved measures of preventing parenchymal liver damage with high protein-carbohydrate diets, high vitamin therapy, the lives of patients with cirrhosis are prolonged, but many of these patients go on to the development of portal hypertension and gastro-intestinal bleeding. It is also evident that the large number of men in the armed forces invalided by damaged livers, the result of infectious hepatitis, will become an increasing problem with the development of portal cirrhosis. The problem of therapy for hemorrhage in cirrhosis will continue to be a serious one. Doctors Blakemore and Lord are publishing a detailed report on the technic of portacaval anastomosis in this number of the *ANNALS OF SURGERY*.

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# THE TECHNIC OF USING VITALLIUM TUBES IN ESTABLISHING PORTACAVAL SHUNTS FOR PORTAL HYPERTENSION\*

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✓EVER SINCE Nikolai V. Eck,<sup>1</sup> a Russian physiologist, successfully performed experimental anastomosis of portal vein to vena cava, in 1877, surgeons have been interested in its clinical application for the relief of portal hypertension. The rare reported instances<sup>2-7</sup> of attempts at the establishment of portacaval shunts by suture, and the by-and-large discouraging results, attest to the technical obstacles to its clinical accomplishment. The technical simplicity and efficiency of the nonsuture method of blood vessel anastomosis using vitallium tubes when employed in the anastomosis of arteries<sup>8</sup> lead to its experimental and clinical trial in the establishment of portacaval shunts.

Basic differences in the hemodynamics of the venous systems *versus* arterial so exaggerate the importance of certain technical aspects in the performance of anastomoses as to make it seem worth while to discuss in some detail the adaptation of the nonsuture method using vitallium tubes to the establishment of portacaval shunts.

At the outset, a general statement may be made, namely, that technical details conceded to be important to the success of arterial anastomosis must be executed with even more meticulous care to insure the success of portacaval shunt anastomoses. ✓The purpose of uniting the portal and caval systems is to reduce portal hypertension and thereby lessen the tendency to gastrointestinal hemorrhage and the formation of ascites. This being true, a shunt capable of handling a large volume of blood should be established.

## SPLENORENAL ANASTOMOSIS

This type of portacaval shunt is capable of handling a large volume of blood and, in addition, has the peculiar advantage of eliminating a sizable portion (estimated at 40 per cent) of the total circulating portal blood volume by splenectomy. So far our clinical experience has been limited to end-to-end anastomosis of the splenic vein to the left renal vein using the nonsuture vitallium tube technic. But, the facility with which an end-to-side anastomosis may be carried out using a vitallium tube affords an alternate method to the sacrifice of the kidney.

## TECHNIC

The spleen is mobilized. In these cases of congestive splenomegaly it is unnecessary to emphasize that extreme caution must be exercised in the control of hemorrhage during mobilization. The vasa brevia are ligated with transfixion sutures of No. 1 Deknatel and the gastrosplenic omentum cut through. Next, the tail of the pancreas is separated from the splenic pedicle

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and the phrenicolic ligament is cut. This now permits freedom of movement of the spleen for a better examination of the splenic vein in the region of its bifurcation.

It is absolutely essential that the full length of the splenic vein be preserved with minimum trauma during splenectomy. In cases with large spleens in which there is persistent bleeding from disrupted adhesions it becomes

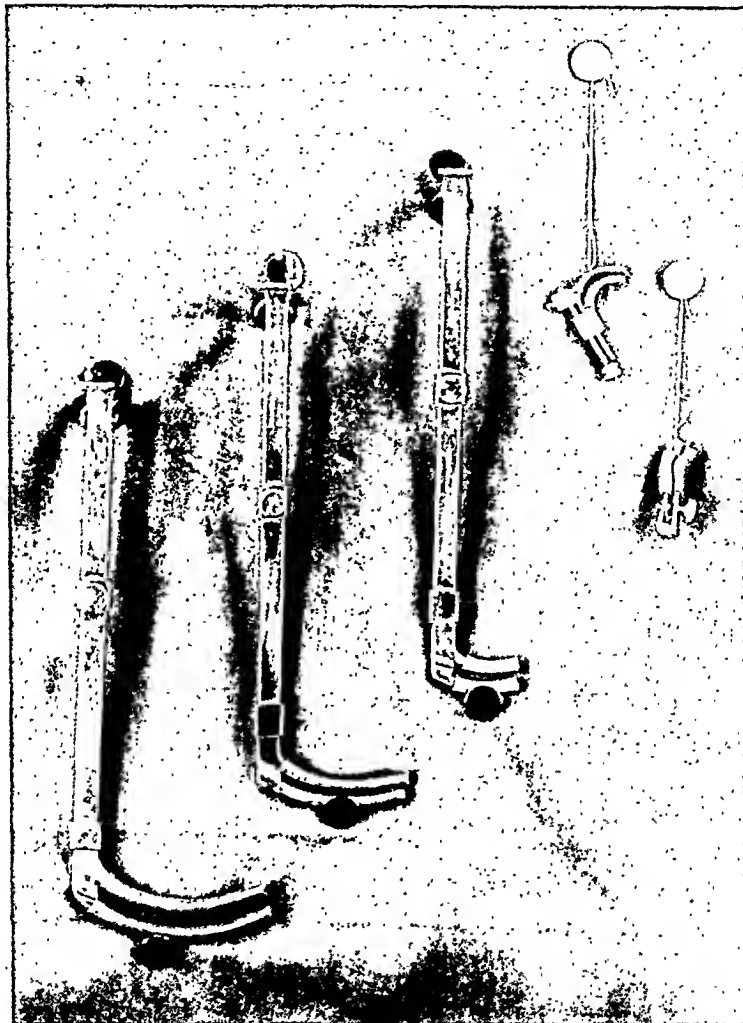


FIG. 1.—Clamps designed by Dr. Armistead Crump for the control of blood flow during the performance of portacaval anastomoses. The two large clamps are suitable for occluding the vena cava. The long handle clamps are easily applied to deep-seated vessels.

necessary to control the splenic artery at once by section between transfixion ligatures of No. 3 Deknatel silk. Otherwise, it may seem wiser, after isolating the artery at the chosen site, to defer ligation until most of the smaller splenic vein branches have been ligated by transfixion ligatures of B and C Deknatel silk. Following ligation of the splenic artery, the spleen may be somewhat emptied of its blood and the splenic vein ligated at once just at its distal primary branching. The blood is then milked far proximalward in the vein and a rubber-shod clamp applied. The smaller rubber-shod clamps illustrated in Figure 1 are handy for this purpose. Immediately following removal of the spleen the stump of the splenic vein should be opened, triangu-

lated with mosquito clamps and thoroughly irrigated with normal saline using a blunt-end syringe.

To effect a comfortable anastomosis of the splenic vein to the left renal vein it is best to mobilize the splenic vein for a distance totaling eight, or more, centimeters. To do this necessitates careful ligation of small pancreatic branches. These branches should be ligated flush with the splenic vein with C Deknatel silk then clamped distally and cut.

A transperitoneal approach is made to the left kidney with retraction of the descending colon medially. The kidney is mobilized and any accessory vessels ligated and cut. The ureter is identified at the lower pole of the kidney, ligated with No. 1 Deknatel silk, clamped proximally and cut. The renal artery is carefully isolated from the vein and ligated at a comfortable site using a transfixion ligature of No. 3 Deknatel. The branching of the renal vein is then studied to make sure that a maximum length of the main renal vein may be preserved for anastomosis. The renal vein is dissected back from the kidney for a distance of five or six centimeters. A rubber-shod clamp is applied as far proximally as possible. The renal artery may then be clamped just distal to the transfixion ligature, cut and again ligated. The vein is sectioned as close to the kidney as possible and the latter removed. Immediately thereafter the stump of the renal vein is triangulated with mosquito clamps and thoroughly irrigated with normal saline.

The splenic vein stump is irrigated with normal saline. A proper-sized vitallium tube (Fig. 2, D) is selected. A tube too large for the vein will present a funnel-like narrowing of the latter after mounting (cuffing). The end of the vein is passed through the tube, triangulated with mosquito clamps and everted (cuffed) over the end of the tube. The vein is held in place by a ligature of No. 1 Deknatel silk placed behind a holding ridge (Fig. 2, A). The tube-mounted splenic vein is freshly irrigated and then wrapped with vaselined gauze.

The renal vein stump is properly trimmed and then triangulated with mosquito clamps. A No. 3 Deknatel silk ligature is laid loosely about the vein. The vitallium tube is grasped with a holding clamp and the intima-covered end is directed toward the renal vein stump. Care is taken to see that neither vein is twisted. They are freshly irrigated with saline, following which the vein-covered end of the vitallium tube is introduced into the renal vein so that the latter comes up well proximal to the tying (holding) ridge on the tube (Fig. 1, A). The previously placed silk ligature is then tied very tightly about the renal vein, approximating it to the splenic vein at a point proximal to the tying ridge upon the tube. A second ligature of No. 3 Deknatel is placed in identical manner. Surgeons knots are essential for the maintenance of the necessary tension in these holding ligatures. Finally, a ligature of No. 1 Deknatel is tied, just snug, about the renal vein approximating it to the splenic vein near the end of the tube. The latter is most important as it keeps blood from penetrating between the two intimas. Figure 1, B shows completed anastomosis. It is arranged to release the rubber-shod

clamp on the splenic vein to be immediately followed by release of the rubber-shod clamp on the renal vein. The distended splenic vein should curve gently to its junction with the renal. Any tendency to acute angulation should be corrected. As much peritonization of raw surfaces as is possible should be carried out and careful ligation of any bleeding vessels before closing the abdomen.

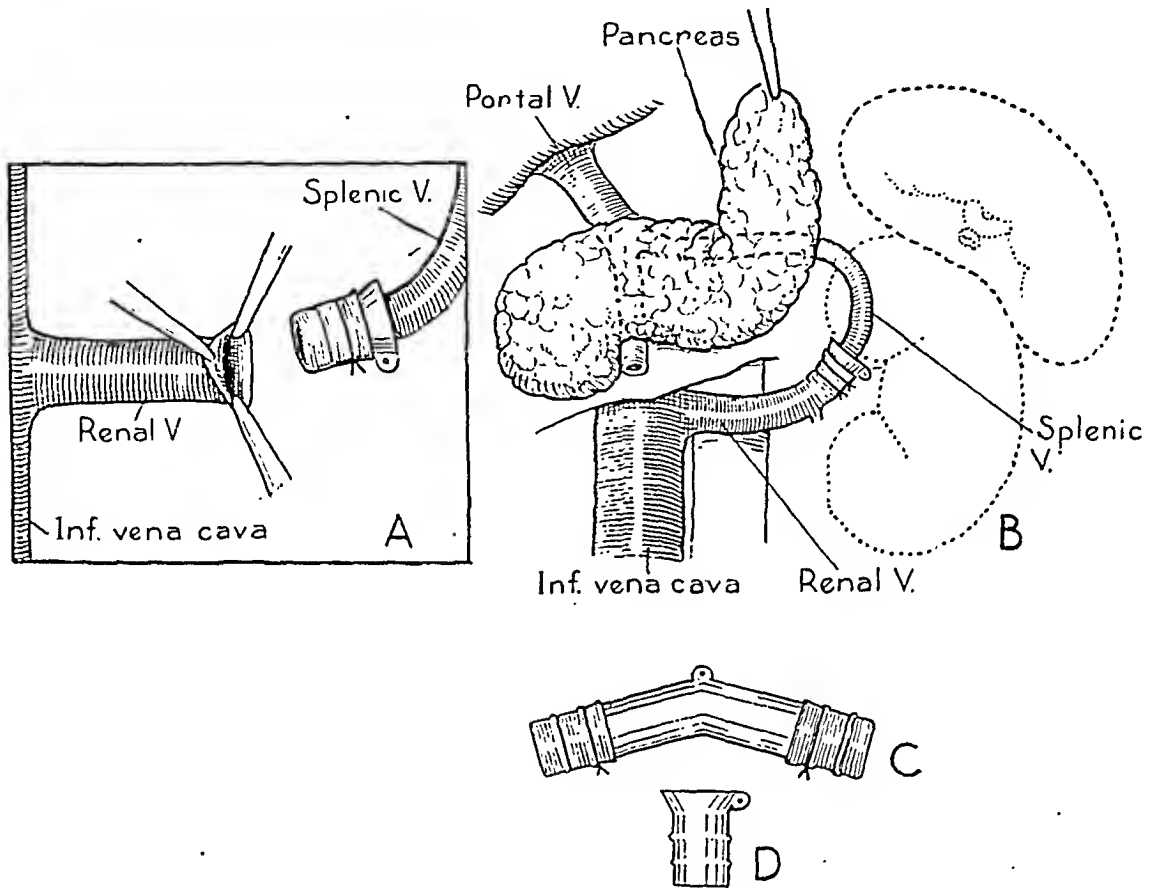


FIG. 2.—A. Illustrating the method of everting the renal vein for the introduction of the vitallium tube bearing the splenic vein. The clamp on the flanged portion of the vitallium tube for its guidance and the rubber-shod clamps upon the splenic and renal veins have been omitted. B. is a semidiagrammatic sketch of the completed anastomosis. Note the placement of the ligatures upon the vitallium tube. C. A vitallium tube with a vein graft mounted. D. An improved design of vitallium tube for end-to-end or end-to-side splenorenal anastomosis. There are two tying ridges placed 2 and 4 mm., respectively, from the end. Note the tab on the flange for the application of a holding clamp.

It is undesirable, for several reasons, to resort to the use of a vein graft in the performance of a splenorenal anastomosis. Though tension and angulation must be avoided, it is our opinion that the use of a graft is rarely necessary providing an adequate length of splenic vein is painstakingly mobilized. In our experience, it was necessary to resort to a vein graft in only one out of five cases. In this case, because of the unusual turgidity of the intervening tissues, due to extreme edema, the splenic vein did not adequately reach the stump of the left renal vein though it apparently had been mobilized over a length of approximately eight centimeters. The gap was bridged using a segment of superficial femoral vein. In the rare case in which the use of a vein graft is indicated, it is our belief that it is best (though this point has not been proven) to employ a vein-lined vitallium tube. Figure 1, C illustrates a vitallium tube, satisfactory in design, for this purpose.

ANASTOMOSIS OF THE PORTAL VEIN TO THE VENA CAVA  
BY THE NONSUTURE METHOD

The Eck fistula type of portacaval shunt has the advantage of size. An end-to-side anastomosis of the portal vein to the vena cava by the nonsuture vitallium tube technic affords an estimated blood carrying capacity 30 to 40 per cent greater than a splenorenal anastomosis.

## TECHNIC

In order to avoid the undesirable use of a vein graft it is necessary to mobilize the portal vein from its bifurcation at the liver to the origin of the splenic vein. At the outset it is best to mobilize the descending portion of the duodenum along its lateral wall. This, with cutting of the hepatoduodenal ligament permits adequate retraction of the duodenum medialward. Since the portal vein lies slightly posterior and medial to the common duct, the above maneuver facilitates medial displacement of the common duct and, hence, permits a lateral approach to the portal vein. Entering the abdomen through a transverse or a right rectus incision with a lateral extension does have the advantage of facilitating a combined lateral and anterior approach to the portal vein. However, whether the approach be combined or anterior only, the common duct is mobilized sufficiently to swing it out of harm's way. The portal vein is carefully mobilized by sharp and blunt dissection. The placing of an umbilical tape or a small Penrose tube about the vein with gentle traction facilitates its dissection. The cystic vein is ligated with C Deknatel silk flush with the portal vein, clamped distally and cut. If the pyloric vein is found at or a few millimeters proximal to the origin of the splenic vein, it may be spared, otherwise it is ligated with C Deknatel silk and sectioned. A rubber-shod clamp is placed on the portal vein at the origin of the splenic vein. A transfixion ligature of No. 3 Deknatel silk is placed around the portal vein at its bifurcation close to the liver, care being taken not to injure the hepatic artery or common duct. The vein is transected four millimeters distal to the ligature. The portal vein is finally irrigated thoroughly with normal saline using a blunt-nose syringe and covered with a moist abdominal pad.

The vena cava is carefully mobilized by combined sharp and blunt dissection from the level of the liver down past the entrance of the left renal vein to the upper level of the right renal vein. The early passage of an umbilical tape about the vena cava with gentle traction serves to facilitate the dissection. Several small vein branches will be encountered posteriorly that will necessitate ligation with C Deknatel silk. A large rubber-shod clamp (Fig. 1) is placed about the vena cava at the upper level of the left renal vein but is not tightened to occlude the vessel.

The portal vein is now passed through a proper-sized vitallium tube. The end of the vein is triangulated with mosquito clamps. The tube is held firmly by a clamp, the end of the portal vein is then everted (cuffed) over the end of the vitallium tube. The vein is held in place by a No. 1 Deknatel

# PORTACAVAL ANASTOMOSIS

ligature tied tightly behind a tying (holding) ridge upon the tube, using a surgeon's knot (Fig. 3). The vein-covered vitallium tube is now swung out from behind the common duct, over the vena cava and a site for the anastomosis is selected. It is most important to select a site that will not result in angulation or compression of the portal vein. The portal vein is again irrigated with normal saline, covered with vaselined gauze to protect the exposed intima and again returned to its former position.

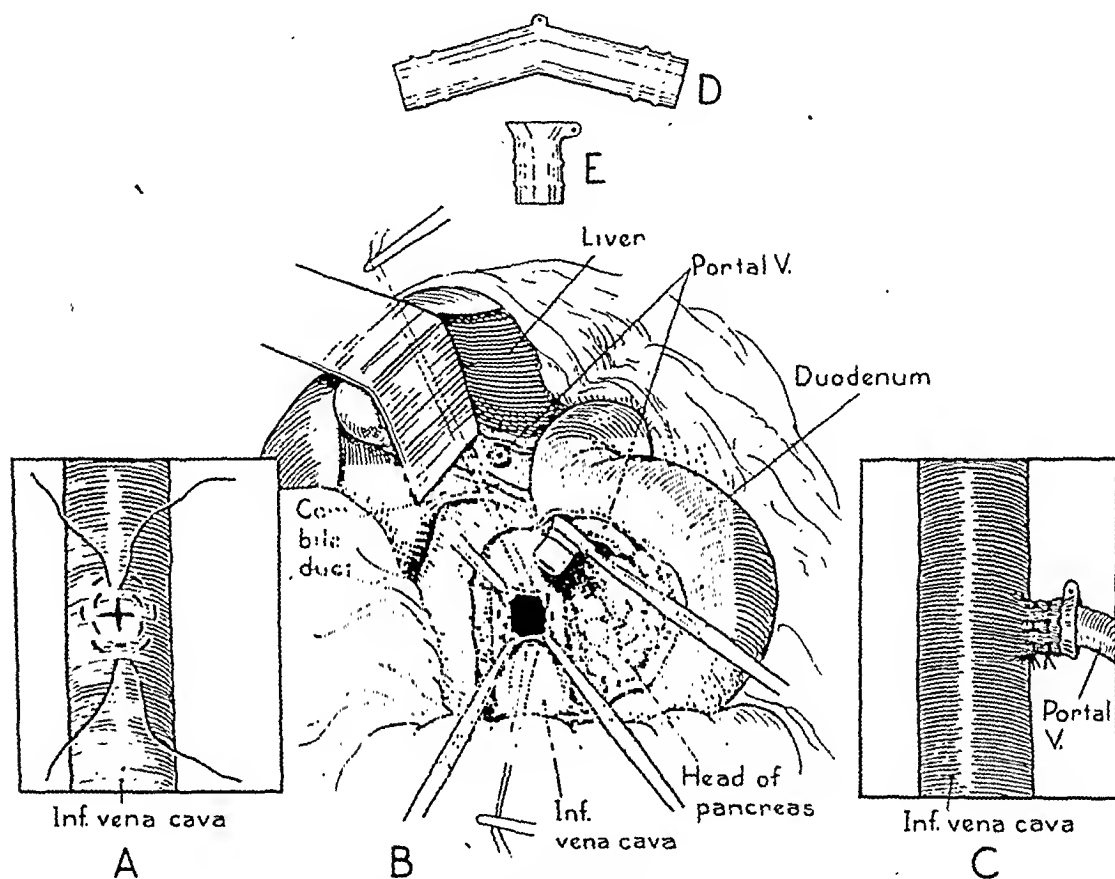


FIG. 3.—A. Illustrating placement of the purse-strings in the vena cava and the centering of the cruciate incision for implantation of the vitallium tube bearing the portal vein. B. shows the tube bearing the portal vein about to be introduced through the opening in the vena cava. C. The completed anastomosis. Note the vena cava wall is drawn well up on the vitallium tube. D. A tube suitable in design for vein graft bridging. E. A late design double-ridge tube with a holding tab.

The area of anterior vena cava wall selected as the site for the anastomosis is cleared of adventitia. New, thoroughly tested No. 3 Deknatel silk, threaded on a small Ferguson needle is introduced as a purse-string in the vena cava wall (full-thickness) at the site chosen for the anastomosis. The silk should be well vaselined before its introduction. The purse-string is introduced to form a circle the diameter of which is four millimeters larger than the diameter of the vitallium tube selected for the anastomosis. A second circular purse-string, starting at the opposite side (Fig. 3, A) is placed two millimeters outside of the first one.

A second rubber-shod clamp is put in position about the vena cava as close to the liver as possible. The distal rubber-shod clamp is now quickly tightened to completely occlude the vena cava at the upper level of the left



renal vein, followed by tightening of the proximal rubber-shod clamp. The time at which the occlusion is made is noted and recorded. A cruciate incision through the vena cava wall, not exceeding in length the diameter of the vitallium tube, is exactly centered within the inner purse-string area. The apex of each quadrant of vena cava wall thus formed is grasped with mosquito clamps and the vena cava irrigated, using several syringefuls of normal saline.

The first turns of a surgeon's knot are placed in each purse-string but not tightened. The vitallium tube bearing the portal vein is grasped with a clamp and advanced through the opening into the vena cava against steady counter traction upon the mosquito clamps (Fig. 3, B). Care must be taken to see that the vitallium tube is not rotated to produce twisting of the portal vein. The vena cava is pulled well up on the vitallium tube so that the inner purse-string, as it is tightened, will fall proximal to the tying (holding) ridge on the tube. The purse-string is finally drawn very tight and the surgeon's knot completed. The holding clamp on the vitallium tube may now be removed and the second purse-string tied just snug about the vitallium tube. The latter will, if correctly placed, tighten about the tube just proximal to the distal ridge. The mosquito clamps may now be removed. Figure 3, C shows the completed anastomosis.

To establish blood flow through the anastomosis first release the proximal rubber-shod clamp on the vena cava. Next release the rubber-shod clamp on the portal vein to be immediately followed by release of the distal rubber-shod clamp on the vena cava. Duration of occlusion of the vena cava is noted and recorded. Finally, the portal vein is inspected for angulation or constriction. Any change of position is noted during the return of the duodenum to its normal position. Omentum may be placed over any unperitonized surfaces. Hemostasis should be checked and the abdomen closed carefully in layers.

Should the use of a vein graft to complete the anastomosis be unavoidable, the external iliac vein more nearly approximates the diameter of the portal vein and only a short segment (6-7 cm.) is required. Figure 3, D illustrates a satisfactory design of a vitallium tube to be lined by a vein graft.

#### SELECTION OF CASES FOR PORTACAVAL SHUNTS

This paper is based upon experience gained in the establishment of portacaval shunts in ten cases (five splenorenal anastomoses, and five portal vein to vena cava anastomoses). As in the case with points on technic, the experience is too limited to express more than formative opinions regarding the selection of cases for operation and the type of shunt indicated in the individual case.

It goes without saying that the selection of cases is based upon a careful history, physical examination and special studies, including kidney function studies. Convincing clinical evidence of portal hypertension should be procurable in the vast majority of cases preoperatively. Furthermore, one can accurately predict, on the basis of liver function chemistry, whether the

portal hypertension is due to intrahepatic (portal cirrhosis) or extrahepatic portal bed block.

A case of splenomegaly giving a history of hematemesis or gastro-intestinal bleeding in association with the presence of anemia, leukopenia, thrombocytopenia and a normal liver function chemistry may be safely diagnosed as congestive splenomegaly due to extrahepatic portal bed block. The splenomegaly may be discovered in infancy or childhood to suggest the presence

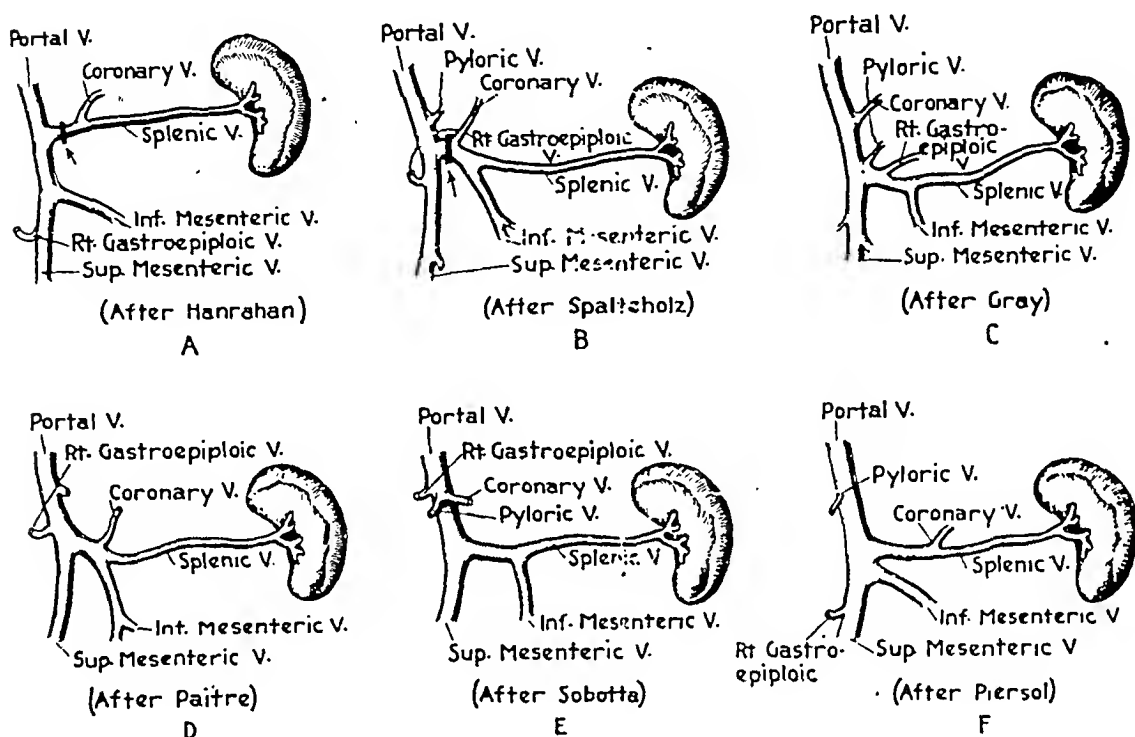


FIG. 4.—Illustrating the anatomic variations in the major branches of the portal vein. Note the effect of a splenic vein block proximal to the origin of the coronary vein.

of portal vein atresia, atresia of the splenic vein at its origin; or, in other cases to follow the history of an injury suggesting splenic vein thrombosis. Rousselot<sup>9</sup> has presented evidence to suggest that congestive splenomegaly when due to a block in the splenic vein may or may not be accompanied by a vicious hypertension localized to the branches of the coronary vein of the stomach (which anastomose with the esophageal veins) in accordance with whether the coronary vein arises from the splenic or the portal veins. If the coronary vein happens to arise from the portal vein, thrombosis of the splenic vein would not, of course, be expected to cause esophageal varices. Or the same would hold in cases in which the coronary vein arose from the splenic vein, provided the thrombosis of the splenic vein were limited to a region of the splenic vein distal to the entrance of the coronary (see Fig. 4). Since four out of the six anatomists list the coronary vein as normally arising from the splenic vein, the chances of a vicious hypertension involving the coronary vein system of the stomach as a threat to hemorrhage from esophageal varices is a real one.

In view of the above facts splenectomy alone as a treatment for congestive splenomegaly should be limited to those cases of splenic vein thrombosis in which the coronary vein arises from the portal vein or, if arising from the splenic vein, the obstruction in the splenic vein must be distal to its origin. Figure 5 illustrates a case in which the above indications were not observed, unfortunately, and there are more about the country. This venogram, made at operation following the injection of a branch of the coronary vein with 35 per cent diodrast, shows the course of the coronary vein (note arrows) directly downward toward the splenic vein. The fact that this patient had a massive hemorrhage six months following the removal of the spleen indicates that the splenic vein was blocked between the origin of the coronary vein and the junction of the splenic with the portal vein. Manometric readings made on a branch of the superior mesenteric vein and another on a branch of the coronary vein at the time of splenectomy had shown a normal reading for the superior mesenteric and an elevated venous pressure in the coronary vein. This finding corroborates the venogram and the subsequent clinical behavior following splenectomy. If the splenectomy had been, at the time, followed by a splenorenal anastomosis, in this case further hematemeses may have been avoided. The only hope of the postsplenectomy bleeders of this particular group would seem to be a vein graft bridging anastomosis of the coronary vein to the left renal vein *via* a thoraco-abdominal, lesser sac approach.

In cases of congestive splenomegaly with a normal liver function chemistry, indicating the presence of extrahepatic portal bed block, the type of surgical therapy must be determined at operation. A quick inspection of the portal vein will determine the presence or absence of cavernomatous transformation. Atresia of the portal vein at the portal fissure may be less easy to recognize. Obstruction sites in the splenic vein, on the other hand, are often extremely difficult to palpate or demonstrate. Venous pressure readings are essential. Figure 6 illustrates a simple device for obtaining readings. Blood pressure in the portal radicals varies normally from 80 to 100 mm. of water. A reading above 110 mm. of water should definitely be considered above normal in our experience. At the outset, a pressure reading should be taken from a branch of the superior mesenteric vein; if this is elevated, it may be taken as evidence of a block in the superior mesenteric vein, portal vein or intrahepatic portal block. A normal reading from a branch of the superior mesenteric vein and an elevated reading from a branch of the coronary vein of the stomach would indicate a block in the splenic vein, and, furthermore, strongly suggest that the coronary vein originates from the splenic vein distal to the site of obstruction. This evidence alone would make us favor performing a splenectomy followed by a splenorenal anastomosis rather than a splenectomy alone. In a case of congestive splenomegaly in which the superior mesenteric pressure is normal, the splenic vein pressure elevated but the coronary vein pressure approximately normal, we would be inclined to perform a splenectomy only. Venography following

## PORTACAVAL ANASTOMOSIS

the injection of 15-20 cc. of 35 per cent diodrast in a branch of the coronary vein is useful in confirming the site of origin of the coronary vein.

In most cases of cavernomatous transformation of the portal vein spleno-renal anastomosis is likely to be the only type of portacaval shunt it is practical to use. In some cases of cavernomatous transformation, however, or



FIG. 5.—Venogram following diodrast injection of a branch of the coronary vein. Arrows point to coronary vein descending toward the splenic vein.

cases of atresia of the portal vein at the portal fissure, in which the spleen has been previously removed, it may be possible to do a portal to vena cava anastomosis using a vein graft. We found it to be feasible in one case.

We are coming to believe that anastomosis of the portal vein to the vena

cava may be preferable to splenorenal anastomosis for the treatment of Laennec's cirrhosis of the liver, though it will take time and more experience to settle this point. In cases of cirrhosis of the liver, having very large spleens, it is logical and safe to ligate the splenic artery in addition if, after the portal vein is implanted into the vena cava, the spleen should fail to shrink satisfactorily at the time. We have not found it necessary to do this so far.

It is our feeling that the larger volume of blood shunted by the portal vein when implanted in the vena cava in comparison to the amount handled by the smaller splenic vein in a splenorenal anastomosis may more effectively lower the portal tension and reduce the tendency to ascites. In regard to the latter, however, the possible use of the left ureter following nephrectomy to drain off ascitic fluid when properly implanted in the peritoneal cavity must not be lost sight of. Studies are in progress in this direction.

✓ **DISCUSSION:** There are two important hemodynamic factors that are known to affect the immediate success or continued patency of blood vessel anastomoses, namely, (1) intravascular pressure; and (2) rate of blood flow. Surgeons experienced in the suture anastomosis of blood vessels are about as certain of the success of arterial anastomoses as they are certain of the failure of vein anastomoses. Arteriovenous anastomoses, on the other hand, can be counted upon to remain patent indefinitely and with unfailing regularity. In the former the high intravascular pressure is an important factor favorable to success. In the latter (arteriovenous anastomosis), in addition to the favorable factor of pressure there is an extreme

FIG. 6.—Photograph of a manometer and tubing arrangement suitable for taking portal pressures and the injection of diodrast for making venograms of the portal bed.

high rate of blood flow, a result of shunting blood from a high pressure (arterial) system to a low pressure (venous) system. These factors insure the perpetuation of anastomoses even though they be formed by the passage of bullets, knives, etc.

It seems likely that the important reason for failure of carefully performed suture anastomoses of veins is the low intravascular pressure. The normal systemic vein pressure is under eight millimeters of mercury. This unfavor-

able factor in combination with cessation of flow due to vasospasm may initiate clotting along the suture line which often rapidly propagates to complete occlusion of the vessel at the site of the anastomosis. The above facts being true regarding the anastomosis of veins in general, the question may very properly be asked, what chance is there of a portacaval shunt remaining permanently open? In the first place, a portacaval anastomosis done for the relief of portal hypertension has the favorable factor of dealing with a greatly increased venous pressure. The portal pressures in our cases ranged from 260 mm. of water (20 mm. Hg.) to over 500 mm. of water (40 mm. Hg.).

✓ A second factor important in perpetuating the patency of portacaval shunts is the extremely high rate of blood flow—the identical factor so important in maintaining the persistence of traumatic arteriovenous fistulae. Though the pressure differential be not of the same magnitude in comparing the two types of shunts, the principle is the same, namely, the shunting of blood from a high pressure (portal) circuit to a low pressure (vena cava), low resistance to flow circuit. It is not unreasonable to venture the statement that the rate of blood flow through a good-sized portacaval shunt may far exceed that of a large artery. In view of the above hemodynamic facts favorable to the perpetuation of portacaval shunts, success or failure in the individual case would seem, then, to depend upon technical factors.

There is full agreement that the ideal technic in blood vessel anastomosis embraces intima-to-intima coaptation without the interposition of a foreign body in contact with the flowing blood. It is conceded that suture anastomoses, when done with meticulous care, may closely approximate the above ideal.

✓ But, in our opinion, its application to the establishment of portacaval shunts is impractical. This is because of the presence of complicating factors that are likely to compromise, at some point, the execution of a uniform technic so essential to the success of vein anastomosis, namely, intima-to-intima coaptation without foreign body contact with the flowing blood. For example, it must be remembered that a beautifully performed suture anastomosis, up to a point, may suddenly be ruined by the malplacement of two or three stitches, the execution of which had been compromised by unfavorable circumstances, such, for example, as inadequate exposure, *etc.*

It is our opinion that the nonsuture method of blood vessel anastomosis is peculiarly suited to the establishment of portacaval shunts. The method embraces the ideal feature of intima-to-intima coaptation without intervening foreign body (suture). It is important to remember that the above feature is approximated only in the "perfect" suture anastomosis whereas, it is automatically assured at the completion of the nonsuture anastomosis, irrespective of the difficulties of exposure, *etc.*, that may be encountered during its performance.

✓ In addition to the greater technical ease with which portacaval shunts may be established, using the nonsuture method, it requires less time than

the suture technic. Time is particularly an important factor in the performance of a portal vein to vena cava anastomosis (Eck fistulae). This is because it is necessary to completely occlude the vena cava proximal to the entrance of the renal veins during the period the vena cava is actually open, *i.e.*, while doing the anastomosis. Serious kidney damage may result from prolonged blockage of the renal veins. It seems likely that this may have been the causal factor in some of the fatalities reported in the early literature following the performance of Eck fistulae employing the suture technic. One may cut down this period of occlusion of the vena cava to a minimum using the nonsuture technic—the time elapsed from the time of incision of the vena cava to completion of the anastomosis may be, and should be, as little as ten minutes.

In conclusion, we may state that every one of the ten cases of portacaval shunts (five splenorenal and five Eck fistulae) went through a successful postoperative convalescence. The interval following operation has been too short in some to judge the results. However, in six of the ten cases the improvement has already been so outstanding as to justify continuing the procedure. The Eck fistula operation is better tolerated by the patient, probably because of less blood loss during the procedure.

#### SUMMARY

A nonsuture method of establishing portacaval shunts by anastomosing the splenic vein to the renal vein or the portal vein to the vena cava, employing vitallium tubes is described and illustrated. The indications for the employment of the two types of shunts are discussed and the technic for each described.

The hemodynamics of portacaval shunts are reviewed with special reference to those features of the nonsuture technic that favor maintained patency of the anastomoses.

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# THE USE OF VITALLIUM TUBES IN STRICTURES AND ABSENCE OF THE COMMON BILE DUCT\*

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STRICTURES OF THE BILE DUCTS are extremely serious lesions since they are so commonly secondary to operative procedures upon the biliary tract, and because operative correction has up to date been relatively unsatisfactory. They must be classified into various types since some are extremely serious and others readily correctable. For example, a short stricture of the common duct which has sufficient proximal and distal duct left for approximation can be reanastomosed with little difficulty and with a favorable outcome. Much more serious is the total absence of the common duct which unfortunately is more common. Undoubtedly portions of the ducts, particularly the distal end, may remain buried in adhesions, thus, making it very difficult to find. The proximal end is usually readily found because of the back pressure of bile which will usually create a bulging structure. It is the group in which no common duct can be found which up to date has yielded such poor results.

In our series of 23 cases of stricture or absence (including two carcinomas of the common hepatic duct) encountered during the past six years, no duct could be found on ten occasions except the stump at the hilus of the liver. In this group we adopted the use of the vitallium tube as introduced by Pearse.<sup>1</sup> After some preliminary trials with different types of procedures, we believe we have established a few principles which have helped us in arriving at a method which yields at least fairly good results in this complete defect which is so difficult to correct.

## ETIOLOGY OF STRICTURES OF THE COMMON DUCT

The causes of benign strictures of the common duct can be divided into five major groups, as shown in Table I. As stated, we conducted a study of 23 consecutive cases encountered during the past six years. Eliminating two which were caused by a malignant tumor of the duct itself, 48 per cent were so definitely related to the original operation of cholecystectomy that trauma appears to have been the direct cause of the stricture. In another 28 per cent the relationship of the stricture to the operation was probable, thus, suggesting that 76 per cent were related to the operation. This is slightly less than the figure of 80 per cent given by Cattell,<sup>2</sup> and of 90 per cent by Walters.<sup>3</sup>

In 9 per cent of our cases the appearance of symptoms before the original

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operation made it appear that the stricture was definitely of the inflammatory type.

In the inflammatory group, ulceration produced by stones may be an important factor in etiology, but other factors including cholangitis and pylephlebitis appear to be more specifically related to it. When the stricture develops slowly after an operation from which the patient recovered slowly because of fever and purulent drainage, there is strong probability that an abscess adjacent to the duct was the primary factor in its destruction. In the entire series (excluding carcinoma) there were six (28 per cent) which we classified as being of the inflammatory type.

We encountered three cases of stricture of the terminal end of the common duct secondary to pancreatitis, constituting an incidence of 14 per cent. The pancreatitis in these three cases was of the severe type from the pathologic standpoint, insofar, as destruction of the pancreas was quite far advanced, particularly in two cases. As would be expected, the strictures were located in the terminal end of the duct and confined chiefly to that portion of the duct passing through the diseased pancreas. From the standpoint of discussion in the literature, these strictures are apparently quite uncommon. They will be discussed in detail in another publication.

TABLE I

CAUSES OF BENIGN STRICTURES OF COMMON BILE DUCT

1. Operative trauma:
  - (a) Excision, ligation or incision
  - (b) Clamped while controlling hemorrhage
  - (c) Cystic duct ligature too close
  - (d) During gastrectomy
  - (e) Following choledochostomy (rare)
2. Ulceration due to gallstones
3. Inflammation
  - (a) Related to cholangitis
  - (b) Abscess about duct
  - (c) Pylephlebitis
4. Secondary to pancreatitis
5. Tumors and multiple cysts

PREVENTION OF STRICTURES

The seriousness of strictures of the common duct makes it imperative that we do everything possible in their prevention. On many occasions, as will be discussed later, ulceration due to gallstones appears to be a reasonably good explanation. Therefore, *early removal of stones* would in reality be indicated. Opinions differ as to whether stones should be removed when no symptoms are being produced by them. Some surgeons are of the opinion that all gallstones should be removed. In elderly people who are asymptomatic, the chances of damage being inflicted from gallstones appears so slight to the authors that cholecystectomy is scarcely indicated. However, we are definitely of the opinion that stones should be removed along with the gallbladder in young patients even though asymptomatic. The chief problem in our minds from that standpoint is the age-border. In general, we feel that if asymptomatic stones are found in people below the age of 40

to 45 and their health is sufficiently good to predict normal life expectancy, the stones should be removed along with the gallbladder.

To eliminate the possibility of strictures resulting from an operation, certain principles in the *prevention of operative trauma* must be adopted and adhered to closely. The authors believe it makes very little difference whether the surgeon starts his dissection from the fundus or from the cystic duct end when performing a cholecystectomy, although they usually start the dissection from the cystic duct end. If adhesions are so dense that dissection at this point becomes dangerous, it seems obvious that the plan should be reversed and dissection started from the fundus, which will allow better isolation of the cystic duct although more hemorrhage will be encountered particularly from the liver bed. Unquestionably this change in technic will minimize the possible damage to the common duct when visualization is so difficult. Safety in gallbladder surgery is strongly dependent upon *good exposure*. The wound should be enlarged until good exposure is obtained. The *cystic duct should be dissected* out down to the common duct until the latter structure can be exposed. The duct and artery should be *tied separately* because ligation in one mass is so inaccurate that the common duct could easily be pinched by the ligature. When working in the region of the common duct, the surgeon must abide by the rule *not to cut any structure until it is completely identified*. He should always dissect by direct vision and not rely on anatomy, although a knowledge of anatomy is of course entirely essential to any surgeon. The reason why the surgeon must not trust the rules of anatomy in dissection about the common duct is because anomalies are so frequent in this area. The *operator must not hurry* while dissecting in the region of the cystic and common duct.

Although strictures very seldom result from the simple procedure of *choledochostomy*, *this operation should be undertaken with extreme care*. Obviously the incision in the common duct for the extraction of stones should be in the longitudinal direction. Particular care must be taken lest the duct be torn transversely. If a transverse tear is produced, the stage is probably set for the development of a stricture later unless an extremely careful repair is made.

#### METHODS OF REPAIR

The method of repair depends entirely upon the type of defect encountered. Defects can be divided into four major groups from the standpoint of the type of technic indicated, as will be discussed later.

There are certain principles in treatment which apply to all types of repair. It is highly desirable to approximate mucosa to mucosa particularly if a supporting tube is not used. Obviously, one should attempt to save all the duct possible. However, in the dissection of the ducts one should minimize the mobilization so as to preserve vascular supply. Nevertheless, on certain occasions when the distal stump is present but short, the duodenum will have to be mobilized to allow contact with the proximal stump. Any tube

must be anchored securely, although no suture will hold longer than a few weeks. Even though silk or wire sutures are applied, they will cut through in due time and the suture fixation will be eliminated. Utilization of rubber tubes has been tried by numerous surgeons but in general the results have not been satisfactory largely because they are usually passed within a short time; within 3 to 12 months after passage of the tube signs of obstruction usually develop. However, we do have two or three patients who have sustained fairly good results following suture over a rubber tube. If they are retained there is a slightly greater tendency for precipitation of bile salts in the lumen than in the lumen of vitallium tubes. It appears well proven that rubber itself acts strongly as a foreign body. Tissue appears to make all effort to extrude the rubber tube. On the contrary, from data up to date, it appears that vitallium is well tolerated by tissue and does not act as a foreign body. All of the rubber tubes which we have inserted (about 15) have been passed. Of 14 vitallium tubes which we have inserted within the last few years, three have been passed.

Although most of the discussion in this presentation is related to the use of vitallium tubes in strictures or absence of the common duct, we wish to emphasize that wherever possible anastomosis should be made with no more than temporary intraluminal support. The indications which we have arrived at will be discussed later under the different types of defects. As suggested above, effort should be made to bring the two ends of the ducts together so that they can be approximated with sutures. However, if this approximation can be achieved only by tension, it will probably not hold. In general, the application of a T-tube to bridge defects achieves the purpose of function quite well. The chief disadvantage of a T-tube is that when wearing it permanently the rubber tube acts as a source of mental irritation to the patient and frequently a source of infection. Almost invariably stricture will result within a variable time after removal of a T-tube if it is inserted in the anastomotic line. Insertion of the tube 2 to 3 cm. distal to the anastomotic line, as performed by Cattell,<sup>2</sup> minimizes stricture formation. Results following the insertion of a T-tube to bridge a defect are commonly so satisfactory that many surgeons suggest this type of operative repair for stricture of the common duct, leaving the tube in permanently.

1. *Local Stricture of the Common Duct.*—This type of lesion is the most readily repaired and, in general, will give the most satisfactory results. Unfortunately it is relatively uncommon. In 23 cases of stricture of the common duct repaired by various technics we encountered a local stricture in only one case (4.5 per cent). In a series of 80 cases reported by Walters,<sup>3</sup> such strictures involving no more than 1 to 2 cm. of the duct were encountered in 15 per cent. In the opinion of the authors there is not a very strong indication for insertion of a vitallium tube in local strictures, although we utilized the vitallium tube in the case just mentioned with very good results. As a matter of fact, cases originally reported by Pearse,<sup>1</sup> who introduced the use of the vitallium tube in repair of bile duct defects, were examples of

this type, *i.e.*, local stricture. It is possible that anastomosis of two ends of the duct together over an arm of a rubber T-tube inserted 2 to 3 cm. distal to the anastomotic line, as practiced by Cattell and others, may be just as satisfactory in such cases, but would not be applicable to the more common defect in which no common duct whatever can be found.

If a vitallium tube is used, the type with a flange on the shaft but without the funnel-shaped end, would appear desirable. The flange on the shaft should prevent the tube from slipping down into the common duct if a

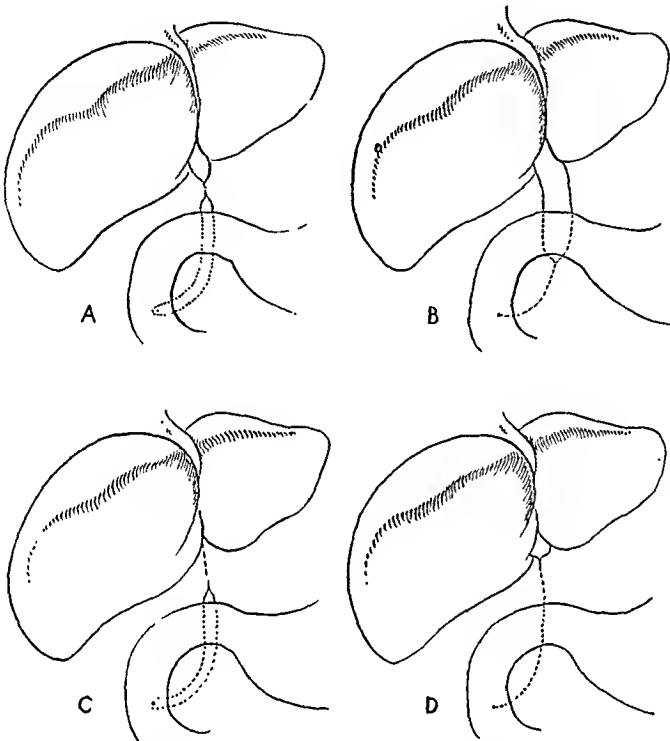


FIG. 1.—Strictures or absence of the extrahepatic bile duct may be divided into four groups, depending largely upon the type of repair indicated. A, Local stricture, B, stricture of the terminal end (seen occasionally in severe pancreatitis), C, stricture of the common hepatic duct, and D, complete absence or stricture.

purse-string suture (of nonabsorbable material) is placed accurately around the distal end of the common duct, distal to the flange. The flange is allowed to protrude in the line of anastomosis.

2. *Stricture or Absence of the Terminal End of the Common Duct.*—This type of lesion will likewise be uncommon but is quite readily repaired. If a few centimeters of the common hepatic duct are present, the authors are definitely of the opinion that transplantation of the duct into the duodenum should be the first operation tried. There is a great tendency for this type of repair to result in a stricture, unless careful efforts are made to attach *mucosa to mucosa* in this repair. If desired this anastomosis may be performed around a rubber tube, several centimeters in length, which protrudes into the lumen of the duodenum. This tube will remain several days, or

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perhaps longer, but will maintain patency for passage of bile during the early postoperative period when edema might otherwise block the duct. This is the type of repair so commonly performed now during resection of the head of the pancreas for carcinoma. Several surgeons<sup>1, 4, 5</sup> have complained of development of cholangitis, with chills and fever, following this

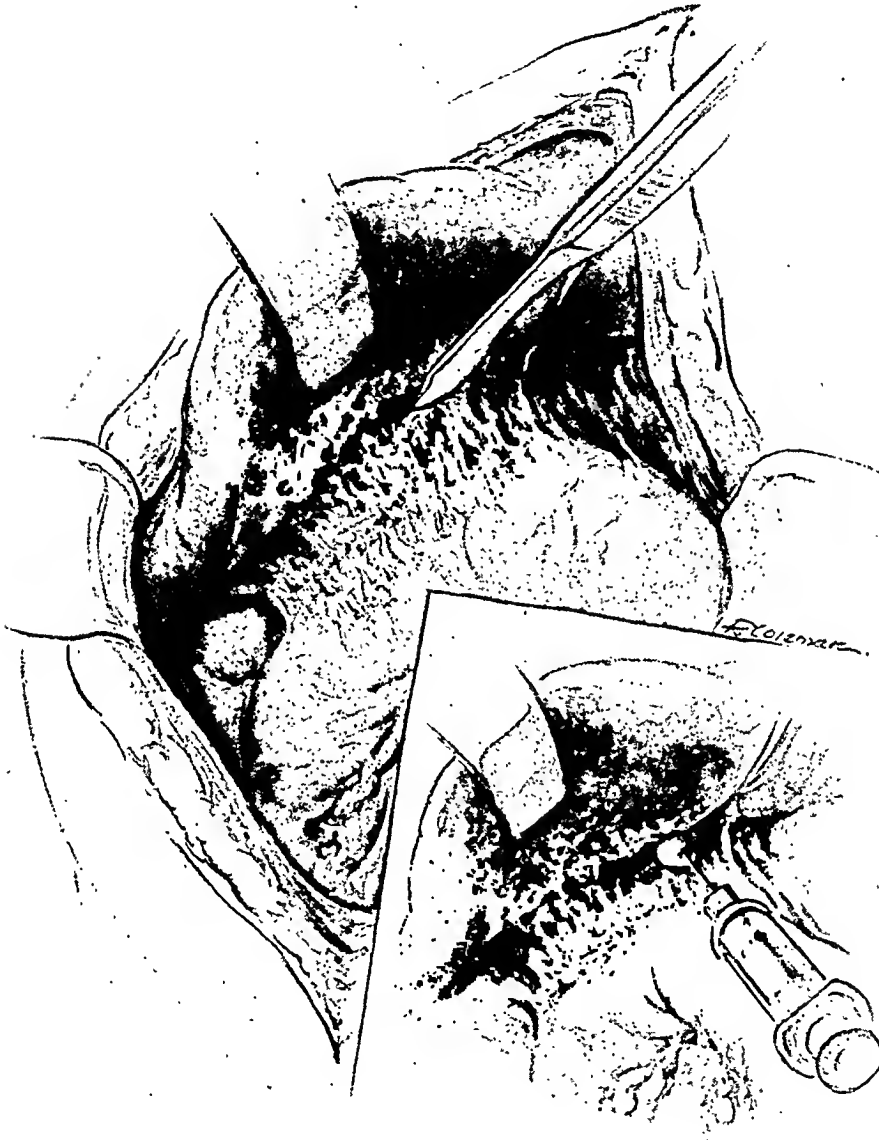


FIG. 2.—Exposure through the dense adhesions is best achieved by dissecting between the liver and intestines with the knife or dissecting scissors, starting from the lateral side. If the duodenum has been attached to the stump of the duct at the hilus previously, the bile duct will be encountered and opened before the portal vein or hepatic artery is reached. Insert shows aspiration of hilus region to identify the duct stump from other structures.

type of repair, although in the majority of cases no symptoms will be encountered at least for several months or a year or two. If a stricture forms or chills become frequent, some type of anastomosis to an isolated arm of the jejunum, as described later, may be advisable.

3. *Absence or Stricture of the Common Hepatic Duct.*—Lesions of this type are more difficult to repair than the two previously described, largely because anastomosis of the duct at the hilus of the liver cannot be achieved with ideal technic. The authors are of the opinion that insertion of a vitallium tube with the funnel end projecting into the stump of the common hepatic

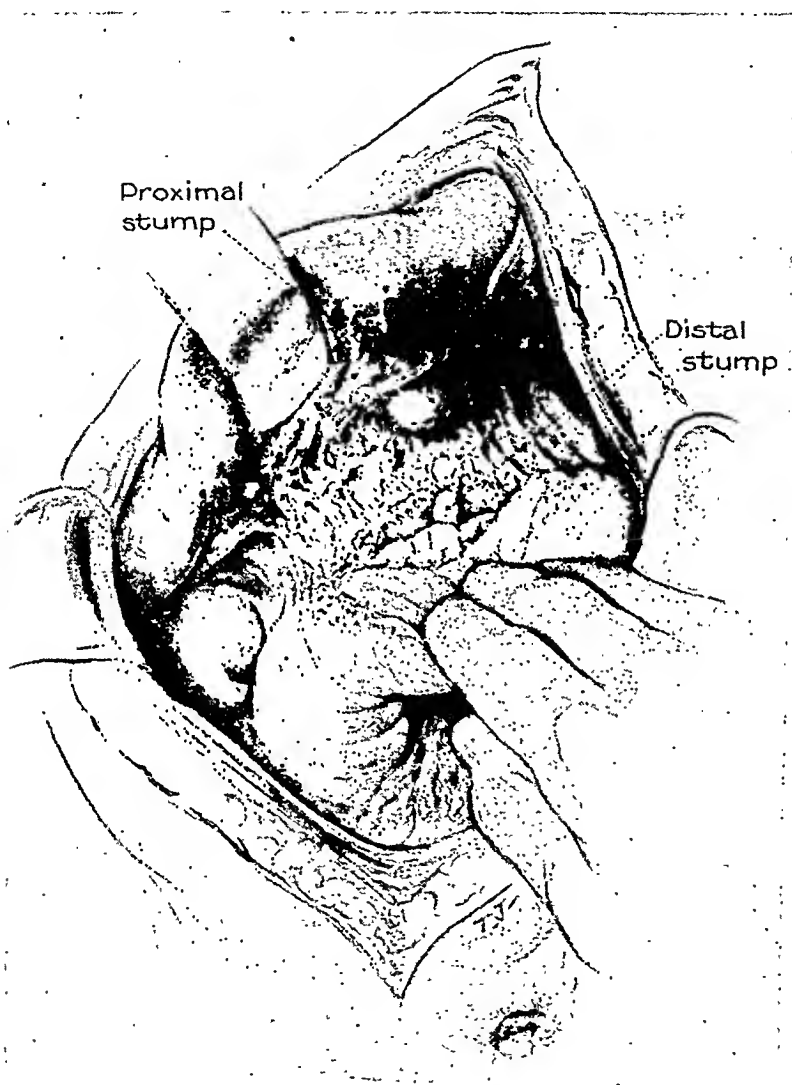


FIG. 3.—Attempt should always be made to find the distal end of the common duct because of the great value of the sphincter of Oddi. Incision of the peritoneum on the lateral and superior side of the duodenum will aid in the search.

duct at the hilus and the lower end protruding into the common duct, as first performed by Clute<sup>6</sup> in this type of defect, is the procedure of choice. Application of a purse-string suture around the opening of the stump of the duct at the hilus serves to anchor the tube particularly when a tube with the funnel-shaped enlargement at one end is used. The distal end of the common duct is then brought up and the tube inserted into it. If possible

the duodenum should be mobilized so that the end of the common duct can be sutured to the hilus of the liver, with the flange in the shaft protruding. If the terminal end of the duct cannot be sutured to the hilus, it *should be anchored firmly* with several interrupted sutures to adjacent tissue because of the danger of the duct slipping off the tube.

4. *Absence of the Common and Common Hepatic Duct.*—When no remnants of the external duct can be found the problem of repair becomes much more difficult. Obviously the only possible method of correction would be

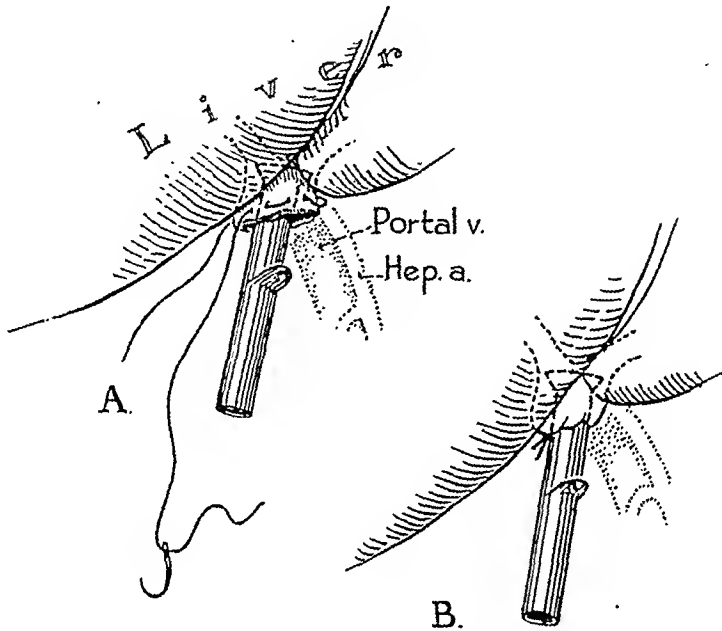


FIG. 4.—A. The stump of the duct is incised or dilated sufficiently to allow insertion of the "funnel" end of the vitallium tube. A purse-string suture is applied,—preferably before the tube is inserted. B. A water tight connection is achieved by tying the suture. If the bifurcation of the ducts is located close to the surface the tube shown may not allow free drainage; a tube with a forked or Y-shaped end will be preferable, since both ducts can then be cannulated.

to anastomose the stump of the common hepatic duct at the hilus of the liver to a loop of intestine. The conventional method utilized up until recent years has been to perform this anastomosis between the hilus stump and the duodenum, usually over a short rubber tube which remains in position for a variable length of time but which will invariably be passed on, since it protrudes into the duodenum where food will dislodge it and carry it along. Dragstedt, and associates,<sup>7</sup> have reported the successful use of a modification of the conventional method of repair in a patient with complete absence of the duct; they constructed a tube from the wall of the duodenum and attached it to the stump of the hepatic duct at the hilus.

Inability to obtain a good anastomosis, and the lack of an appreciable amount of duct wall are largely responsible for the poor results in plastic operations when no duct can be found. A stricture forms in the line of anastomosis in a majority of the cases, although now and then the patient has a good result with very little if any evidence of obstruction or cholangitis. Cholangitis is the pathologic lesion feared in any repair of this type (*i.e.*, total



absence of the duct). Symptoms consist primarily of chills and fever; however, the great danger is development of multiple abscesses of the liver.

As will be discussed later under "Comment," we are of the opinion that in addition to stricture formation, reflux of food and intestinal secretions into the intrahepatic ducts is very important in the development of cholangitis. If this is true we should obviously adopt an operative procedure which would minimize that complication. Since we have no method of constructing an artificial sphincter it appears we should attempt mechanically to prevent reflux of

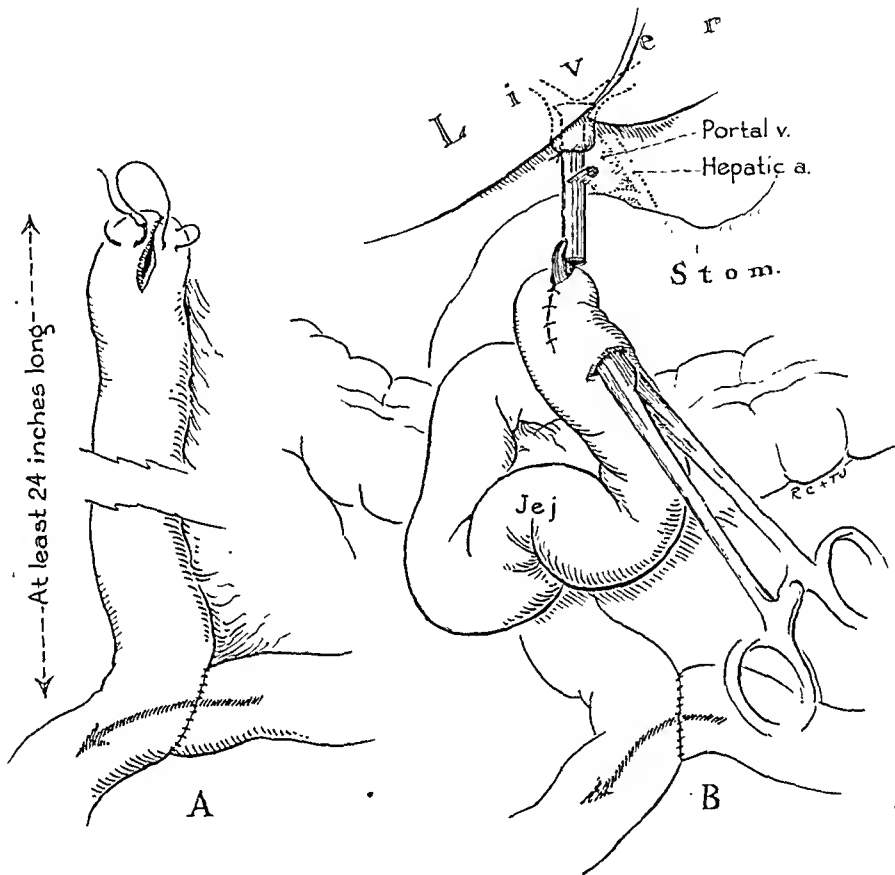


FIG. 5.—After the ileum is severed and the proximal end sutured to the distal loop two to three feet from the point of severance, the distal end is closed with a continuous suture as shown in A. The end of the vitallium tube is inserted into the end of the intestine, aided by a hemostat threaded through a puncture wound two inches from the closed end as shown in B.

food up through the line of anastomosis into the liver by isolation of the area from the food stream. Two methods of construction could be used to accomplish this principle: (1) Anastomosis of the hilus stump to an arm of the jejunum after the Roux principle (see Figs. 5 and 6); or (2) attachment of the hilus to a loop of jejunum in which an anastomosis is performed between the two loops at a distance from the hilus anastomosis (see Fig. 7). We have utilized both of these principles in construction of an intestinal loop to transport the bile, but have had better results with the method utilizing the single arm

of jejunum utilizing the Roux principle. We will, therefore, describe this method in more detail.

(1) *Anastomosis of the Hilus Stump to a Single Arm of Jejunum*

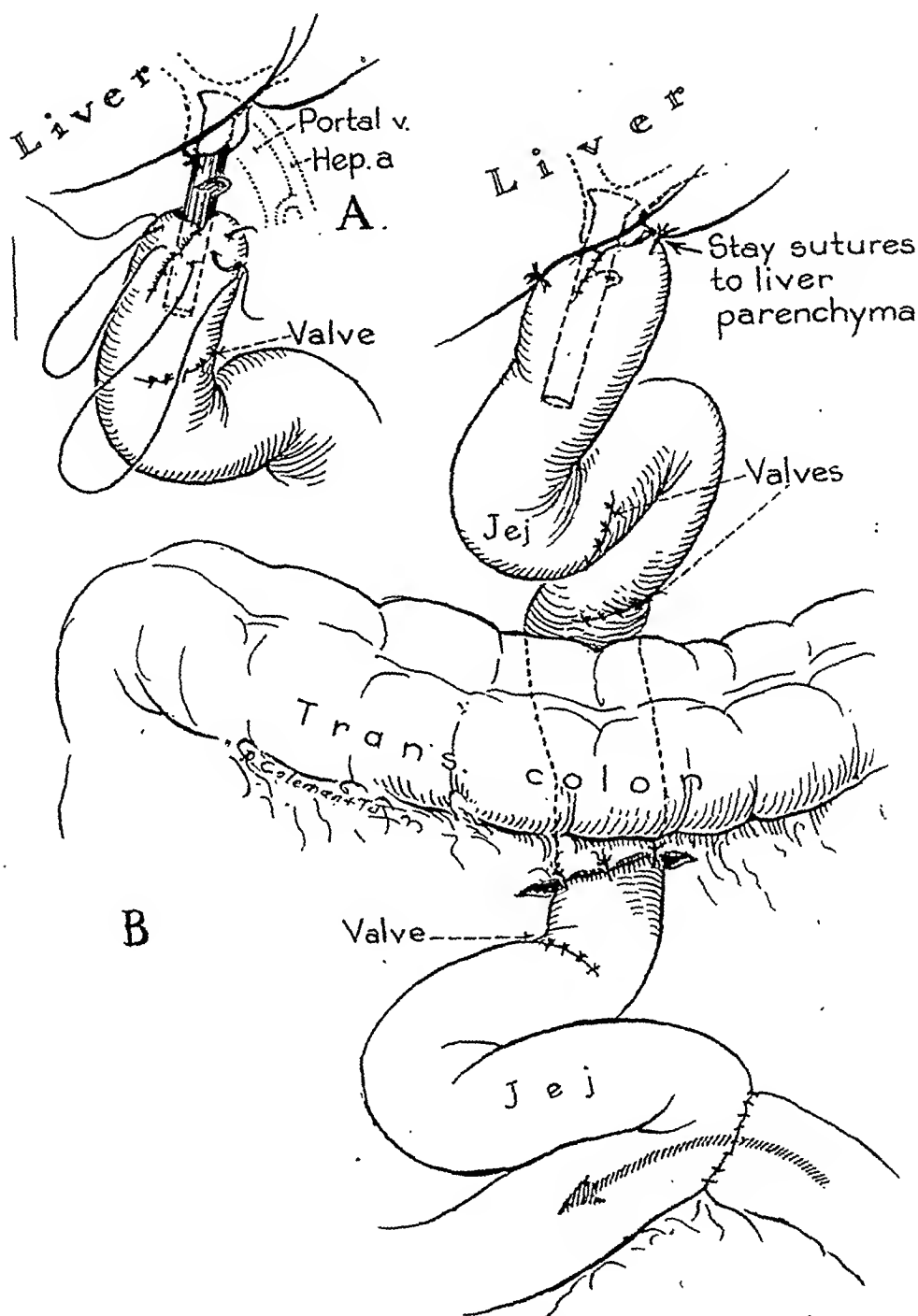


FIG. 6.—A. The connection between intestine and distal end of the vitallium tube is made tighter by application of a purse string suture of silk or cotton which is more easily applied before the tube is inserted. B. The end of the intestine is anchored against the liver by interrupted sutures all of which should be inserted before any one is tied.

*Utilizing the Roux Principle.\**—Commonly the patient has already had two

\* Since preparation of this manuscript Allen has published an article (ANNALS OF SURGERY, 121, 412, 1945) describing a similar use of the Roux arm of jejunum, except that a rubber tube was used.

or three operations before coming in for repair of the stricture. Adhesions are practically always extremely dense because of the infection and irritation of the bile incident to the biliary fistula. Therefore, care must be exercised in dissecting down toward the region of the common duct lest the intestine be damaged. The colon is usually densely adherent to the abdominal wall

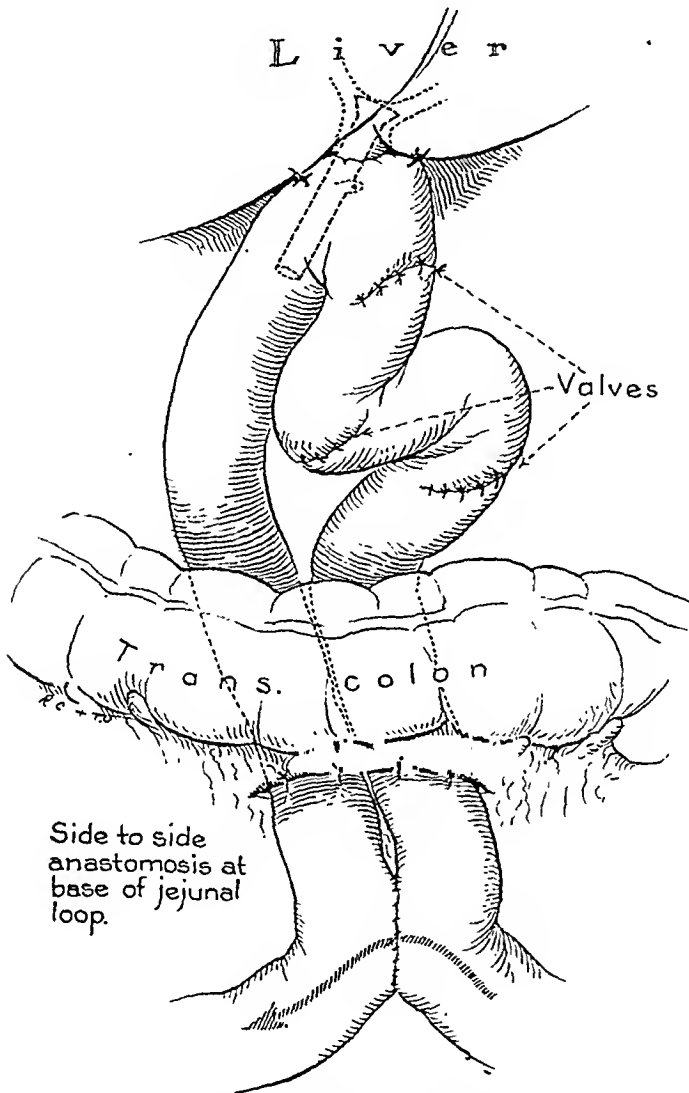


FIG. 7.—An alternative and shorter method of constructing an outlet of bile to a defunctionalized portion of intestine is to insert the vitallium tube into a loop of jejunum. An entero-enterostomy should be performed 18 to 24 inches from the point of insertion of the tube. However, in our experience this method has ultimately been followed (as late as two years) by severe cholangitis presumably because of reflux of food and intestinal contents into the liver. Construction of valves as illustrated in Figure 8 might minimize this tendency.

and ventral surface of the liver. The duodenum is usually plastered densely against the hilus of the liver beneath the colon. Dissection, bluntly or by scalpel, can best be performed by staying close to the ventral surface of the liver and working from the lateral side down towards the region of the common duct. Effort should first be made to locate the common duct or its

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remnants. The duodenum can be mobilized by incising the peritoneum along its right border hoping to find a remnant of the distal end of the common duct as the duodenum is rotated toward the midline. However, the dense adhesions which are so consistently present make isolation and discovery of the distal end of the common duct extremely difficult and, in fact, unlikely. As will be discussed later, in the majority of cases in our series we were unable to find any remnant of the common duct except indefinite fibrous bands. An incision can be made in the duodenum over the sphincter of Oddi hoping

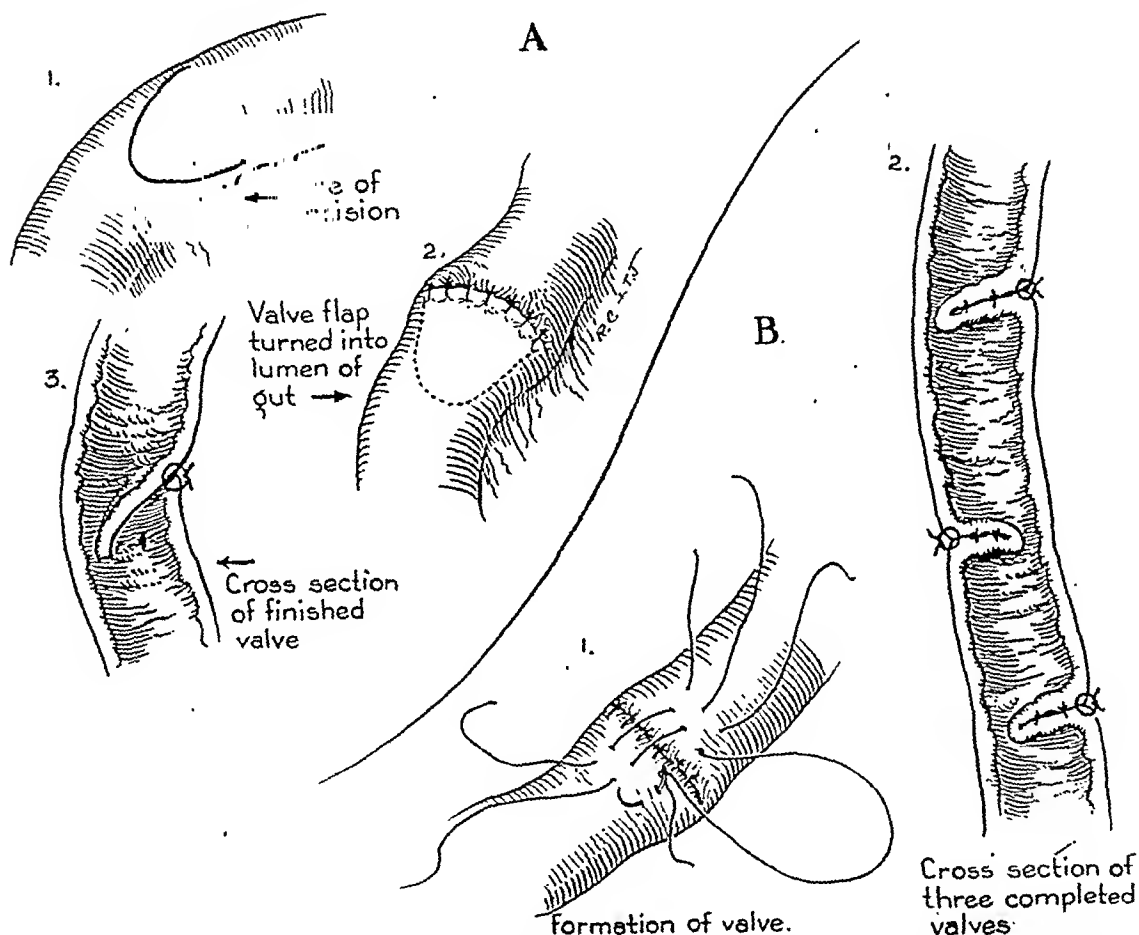


FIG. 8.—In our experience the construction of valves of one of the two types illustrated above eliminates reflux of food (as indicated by barium studies) and has minimized or eliminated the cholangitis. A. A valve may be constructed by outlining a flap of intestine and closing the defect after inverting the flap into the lumen. B. The creation of baffles by a double layer of sutures infolding the wall of the intestine into the lumen are probably as effective as A and are much more simply constructed. At least three of these folds should be made. No claim for originality is made for these valves since similar ones have been reported for various purposes during the past several decades.

to find this structure and, thus, locate the distal end of the duct. We have been extremely unfortunate, however, in locating the duct or sphincter by this method. We have recently discovered an explanation of this difficulty, insofar, as we have found a stricture at the sphincter level on several cases, as will be described in another publication. If an incision is made in the duodenum it should be made longitudinally and closed transversely, after the Mikulicz technic.

If it is demonstrated that no common duct is available, attention should be centered on the localization of the stump of the hepatic duct at the hilus.

If another plastic operation, such as hepatoduodenostomy, has been performed previously, the anastomotic line can be located easily by incising from the lateral side toward the point of fixation between the hilus and the duodenum. This will cut into the strictured area without endangering the portal vein or hepatic artery. The safety of this approach to the hilar structures is appreciated more fully when we realize the seriousness of incision into the portal vein or hepatic artery. If no previous operation of this type has been performed, the stump of the duct is located by aspiration with an hypodermic syringe and needle. On some occasions the duct appears actually to be buried in the liver tissue. Frequently it contains white bile and not normal colored bile.

The lack of sufficient amount of hepatic duct for an anastomosis is ample explanation for the high percentage of failures without the use of a permanent tube of some type. Insertion of a vitallium tube through the stump of the hepatic duct into the lumen of a functioning intestine (usually duodenum) would appear to result always in passage of the tube sooner or later. We have not attempted this type of anastomosis because it appears to us that the food stream would inevitably dislodge the tube. Certainly it has been true with the use of rubber tubes. As indicated above, we have utilized the principle of using a blind loop of jejunum to anastomose to the stump of the hepatic duct. We have likewise discovered that the amount of intestine intervening between the anastomotic line at the hilus and the intestinal anastomosis where the food enters must be at least 24 inches (see Fig. 6) because food can regurgitate for several inches into a blind defunctionalized loop.

After the stump of the common hepatic duct is located at the hilus the jejunum is identified and severed about one foot or more from the ligament of Treitz. The distal end is closed by inverting with a single suture of continuous catgut. The end of the proximal loop is then anastomosed to the distal loop at least two feet from the end which is to be attached to the duct at the hilus of the liver. It is immaterial which type of anastomosis is utilized, although the end-to-side seems appropriate to us; if desired, the end of the proximal loop could be closed and a side-to-side anastomosis performed. The arm of the jejunum to be anastomosed to the stump of the duct is then placed in position to see if the mesentery of the jejunum is long enough to reach around the colon and allow anastomosis between the duct and intestine without tension. If the mesentery is long enough an anterior anastomosis is performed. If it appears too short to reach around the colon then it is preferable to make an opening in the mesocolon and draw the arm of the jejunum up through this opening. If this is done, the edges of the opening in the mesocolon must be anchored to the jejunum and its mesentery, lest loops of intestine invaginate into the opening in the mesocolon and become obstructed. The opening of the common hepatic duct at the hilus is then dilated to a size which will allow introduction of the funnel end of the vitallium tube. With a probe or curved blunt instrument the right and left

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hepatic duct can be located easily. Occasionally the duct will divide so close to the hilus that the ordinary tube will be blocked by the septum between the ducts. Under such circumstances, a tube with a "Y" end should be used so that each duct is cannulated. It so happens that in all except one of our cases the duct has divided high enough in the liver to allow us to use the ordinary vitallium tube with a funnel end. A purse-string suture of silk or

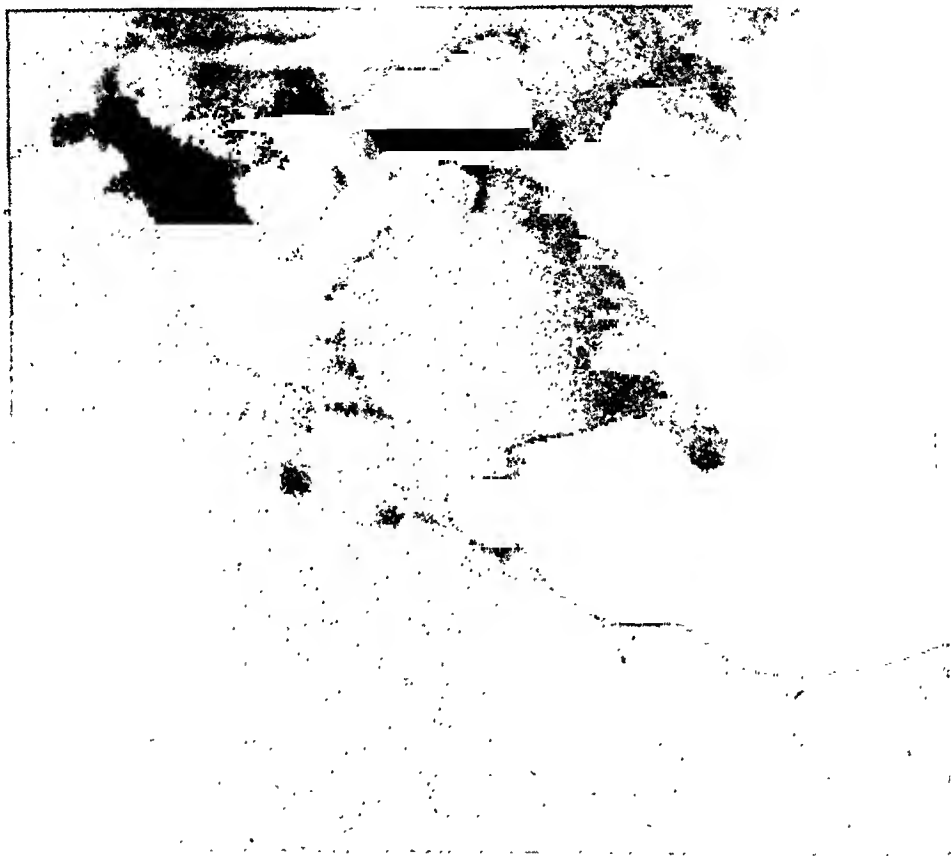


FIG. 9.—X-ray of the liver after a barium meal in a patient who had had the conventional anastomosis between the duodenum and stump of the common hepatic duct for a complete absence of the common duct. The anastomosis was performed over a rubber tube which was passed a few weeks later. Note the massive regurgitation of barium into the dilated intrahepatic ducts. He is having frequent chills and needs another type of repair.

cotton is then placed around the end of the duct and the tube inserted. Tying the suture should anchor the tube securely. Since the portal vein lies adjacent to the bile duct, there is danger of puncturing it when applying the suture on this side. If there is doubt about the position of the portal vein when the purse-string suture is applied on the medial side, this area may be aspirated with an hypodermic needle. If at least 2 or 3 mm. of tissue intervene between the duct and the vein, the suture can be taken without endangering the portal vein. It would be highly undesirable to place the suture through the wall of the vein since the trauma might encourage thrombosis or thrombophlebitis. A purse-string suture is then applied around the center of the line of closure at the end of the arm of jejunum. A small opening is made about two inches from the end and a curved Pean forcep inserted (see Fig. 5B). A tip of the forcep is threaded through the closed end of

the jejunum between the linear sutures and through the purse-string. The end of the vitallium tube is then grasped and pulled into the end of the jejunum and the purse-string suture tied. This then allows the intestine to be fixed against the hilus of the liver with the certainty that the tube is adequately threaded through the end of the jejunum into its lumen. Interrupted sutures are placed anchoring the end of the intestine against



FIG. 10A.—X-ray of liver after a barium meal in a patient in whom we had performed an anastomosis between a loop of jejunum and the stump of common hepatic duct at the hilus of the liver (as in Figure 7) reveals regurgitation of a moderate amount of barium. Development of chills and fever led us to the decision to interrupt the proximal loop to prevent regurgitation.

the hilus of the liver. The capsule of the liver is always tough, thus, allowing application of the sutures without danger of hemorrhage or tearing. It is easier to insert these sutures before the vitallium tube is inserted into the end of the intestine; if they are placed before the intestine is put into place they can be tied readily while the tube is being held in position with the Pean forcep. The opening made in the end of the intestine to admit the forcep is then closed with one or two purse-string sutures or a few inter-

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rupted sutures. We believe that some type of valve, or baffle, should be made in this arm of jejunum to prevent reflux of intestinal contents upward into the intrahepatic ducts. It is perhaps adequate to insert several interrupted sutures so as to fold the wall of the intestine into the lumen. At least two or three of these folds or valves should be made. The wound is then closed leaving a rubber drain in the upper portion. This drain should be

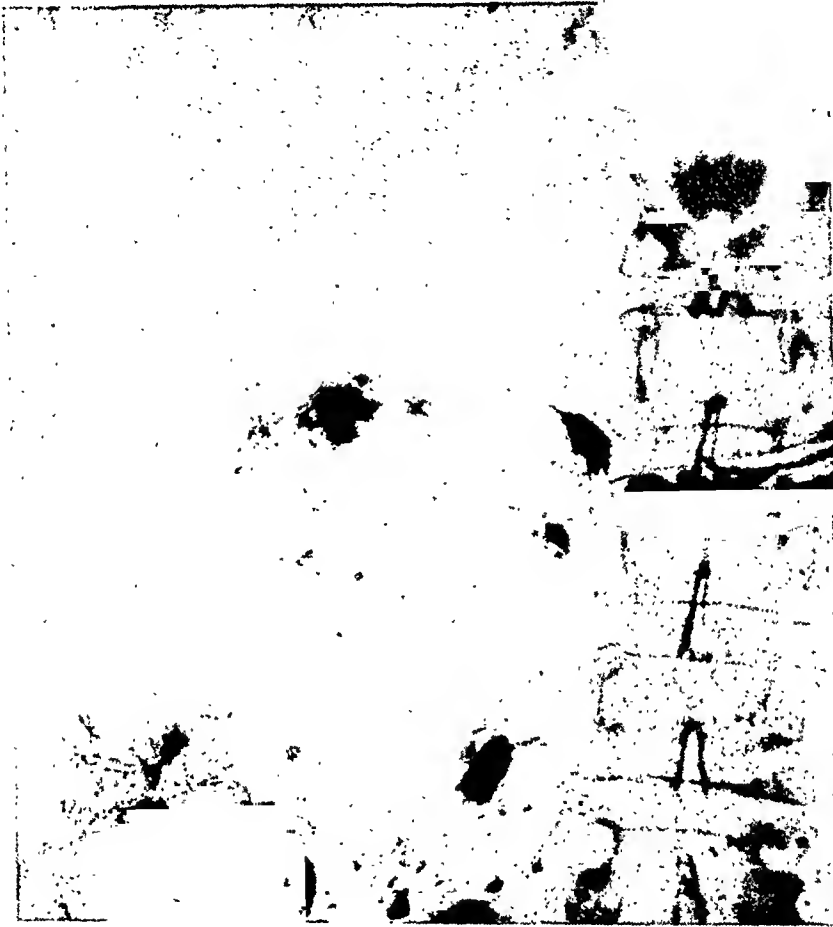


FIG. 10B.—After we interrupted the proximal loop and made valves in the distal loop to further minimize regurgitation, no barium reached the intrahepatic ducts following a barium meal. The chills and fever have now disappeared. In the meantime the vitallium tube has been passed; however, it would appear that passage of the tube would have little to do with elimination of regurgitation since the patient in Figure 7 without a vitallium tube has a massive regurgitation.

left in place for four to six days since a biliary or intestinal fistula may develop any time during this interval.

(2) *Anastomosis of the Hilus Stump to a Loop of Jejunum.*—Anastomosis of a loop of jejunum to the stump of the hepatic duct at the hilus requires less operating time than an anastomosis of the end of the jejunum after the Roux-“Y” principle, as discussed above. However, three of the four cases surviving this type of operation developed chills and fever after a variable length of time following operation; one died, whereas the fifth case has only a fair result now. Therefore, we do not recommend this type of anastomosis unless an effective valve, or baffle of some type, is placed in both arms of the loop, particularly on the proximal side. The same princi-



ples described under (1) apply to this type of anastomosis. A loop of jejunum is placed in position around the colon upward toward the hilus of the liver to determine whether or not the mesentery is long enough to reach around the colon. If not, an opening must be made in the mesocolon and the loop of jejunum brought up through the opening. The funnel end of the vitallium tube is anchored in the end of the duct at the hilus with a purse-string suture, and the other end inserted in a small opening at the end of the loop and likewise anchored with a purse-string suture. Interrupted sutures are placed at three or four points between the end of the loop and the capsule of the liver around the duct before placement of the tube in the jejunum, and are tied after the tube is anchored with the purse-string suture. An entero-anastomosis must be made between the two loops of intestine, but at least 12 inches away from the anastomosis between the duct and the end of the jejunal loop. The wound is closed leaving a drain in the upper end of the wound as in the operation just described.

#### ANALYSIS OF CASES AND RESULTS

As stated previously, we have inserted 14 vitallium tubes in the treatment of stenosis or absence of the common duct. On ten occasions the tube was used when no common duct whatsoever could be found. In five of these cases an anastomosis utilizing the Roux-"Y" principle, as illustrated in Figures 5 and 6, was the procedure utilized. The results in four of these five patients were good to excellent. The results in the fifth case were completely clouded because of the coincidental development of a splenomegaly of the Banti's type. We do know, however, that the opening had allowed free access of bile to the intestinal tract in this patient because the stools have not been clay-colored. In the other five cases, anastomosis of a loop of jejunum to the stump of the duct at the hilus was performed (see Table II). Of these five patients, one died of hepatic insufficiency and postoperative infection. Of the remaining four, two had a fair result for two years but then began having chills and fever. The other two had fairly good results for a few months but within a year developed chills and fever. We have interrupted the proximal loop of jejunum in three of the four patients. This procedure resulted abruptly in cessation of the chills and fever in two of the cases; insufficient time has elapsed following operation in the third case to allow formulation of any conclusion regarding outcome. The fourth patient is now having chills and fever after two years of excellent result, and an operation has been recommended to sever the proximal loop.

Comparison of the results in these two groups of patients reveals that the operation utilizing the Roux arm (as in Fig. 6) is far superior to the operation anastomosing a loop of jejunum to the duct at the hilus (as in Fig. 7).

Of the four remaining cases, one had a carcinoma of the common hepatic duct; after excision of the carcinoma an anastomosis was made between the stump of common hepatic duct and the common duct over a vitallium tube,

TABLE II  
CONDENSED SUMMARY OF CASES OF STRICTURE OR ABSENCE OF COMMON DUCT TREATED BY IMPLANTATION OF A VITALLIUM TUBE

Case No.	Type of Obstruction	Type of Operation	Sex	G. R. Removed	Repair Operation	Convalescence	Remarks	Results
1.		Duct at hilus of liver anas. to single arm (Roux - "Y") of jejunum (See Fig. 6)	F	Aug. 1941	May 1943	Uneventful	Feeling fine since oper. except for epigastric pain. Had 3 chills since oper. No jaundice or acholic stools	Good to excellent
2.			F	Dec. 1941	April 1943	Uneventful	No complaints since last oper. except one chill on 7-1-44. No jaundice	Excellent
3.			F	Feb. 1943	July 1944	Satisfactory	Since oper. has gained 40 lbs. Had a few chills early but none during past 4 wks. Still has draining sinus in wound (osteochondritis?)	Excellent (except for draining sinus)
4.			F	Jan. 1943	May 1943	Uneventful	Very few complaints. Is feeling better than previous to all opers., including the first	Excellent
5.	No common or com. hep. duct found		F	March 1943	April 20 and 26, 1944	Stormy. Atelectasis and stubborn distention	Large spleen found at reparative oper. has increased in size (Banti's?). Stools normal color. Still jaundiced but no evidence of duct obstruction. Ascites	Clouded by development of Banti's syndrome
6.		Duct at hilus of liver anas. to loop of jejunum (See Fig. 7)	F	Dec. 1941	June 1942	Uneventful	Symptom-free for 2 yrs.; then chills and fever, without jaundice. Needs proximal loop severed	Excellent for 2 yrs. Now only fair
7.			F	May 1935	5 oper. 1936 to 1943	Uneventful	Four anastomoses done over a rubber tube failed. Insertion vitallium tube into loop of jejunum afforded relief for 2 yrs., then developed multiple liver abscesses and died	Excellent for 2 yrs. then chills, liver abscesses and death
8.			F	April 1940	May '42 Jan. '40 (valve)	Biliary and int. fistula following 2nd oper., but healed in 2 wks.	Symptoms recurred after 1st oper., because of reflux into ducts? Interruption of proximal loop to prevent reflux abolished symptoms	Excellent since 2nd oper.
9.			F	May 1938	Feb. '42 Oct. '43	Uneventful	Anastomosis with continuous loop of jejunum failed, but 2nd oper. interrupting ascending loop abolished symptoms	• Excellent since 2nd oper. (but developed arthritis and cardiac symptoms)
10.			F	Aug. 1942	Jan. 1943	Postoper. wound infection. Hepatic insufficiency	Anorexia, weakness, malaise increased, with reversal of blood protein. Primary cause of death hepatic insufficiency	Died
11.	Defect or Ca. in com. hep. duct. Distal com. duct found	Hilus duct anastomosed to com. duct	F	Jan. 1943	Oct. 1943	Uneventful	Has had an occasional mild chill. Also some epigastric pain	Good to excellent
12.			F	None	April 1944	Developed pyloric obstruction requiring a secondary operation	Had a resection of a Ca. of C.D. Repaired duct over a vitallium tube. Few mild chills. One attack of jaundice	Good to excellent
13.			F	Sept. 1943	Oct. 1943	Stormy. Wound infection and peritonitis	Numerous large intra-abdominal abscesses were drained. At autopsy, many small liver abscesses found	Died
14.	Prox. and distal duct found	Com. hep. duct to com. duct	F	May 1942	June 1942	Uneventful	Had one attack of jaundice and acholic stools of one week's duration early after oper. Otherwise no complaints	Excellent after operation

thus, preserving the sphincter of Oddi; results have been excellent in this patient up to date (one year). In two of the four cases no common hepatic duct could be found; an operation of the type just described was performed. One patient died, but the results in the other case were good to excellent. The remaining case had a local stricture of the duct. A sizable stump of common hepatic duct and common duct were found. A vitallium tube was placed between the two stumps of the duct, although the use of the tube may not have been necessary. The results in this patient were excellent.

#### CASE REPORTS

**Case 1.**—Patient (No. 89020) was a female, age 23, who entered the Illinois Research Hospital on May 15, 1943, complaining of constant icterus following a cholecystectomy performed elsewhere, in August, 1941. There was no jaundice previous to operation. On the 14th postoperative day she had a celiotomy in an hospital elsewhere, at which time a T-tube was placed in the common duct between two cut ends. Eight months later the tube was removed; this was followed in a short time by itching and jaundice. In the meantime she became pregnant and six months later was delivered of a five-pound baby. When she entered Illinois Research Hospital she had evidence of complete biliary obstruction. Stools were completely acholic. Weakness and malaise were pronounced. The red blood count was 4.1 and the hemoglobin 80 per cent.

*Operation* for correction of the biliary obstruction was performed at Illinois Research Hospital, May 17, 1943. A moderate number of adhesions were encountered. These were dissected loose, uncovering the area where the common duct should be. We found one small cord which might have been a remnant of the common duct, but after considerable dissection, finally were convinced that a lumen did not exist in that area. One or two structures which we thought were portal vein were aspirated and blood obtained. The duodenum and upper margin of the pancreas were fairly easily mobilized, thereby making us more certain that no common duct remained. We, therefore, decided that we would have to find the stump at the hilus of the liver and establish an anastomosis of some type between that and a loop of small bowel. The patient was rather small and had a narrow outlet to the thoracic cage. This did not leave much room for bringing up a double loop to insert against the hilus of the liver since duodenum and liver largely filled up the right upper quadrant. We, therefore, decided that one arm of the jejunum, after the Roux principle, would be preferable to a double-armed loop. We accordingly cut across the lower jejunum and brought up the distal segment through an opening in the mesocolon and attached it to the stump of the duct at the hilus of the liver, anchoring a vitallium tube in place connecting the two structures. The intestine was anchored with three or four interrupted sutures to the hilus of the liver. The proximal end of the cut jejunum was then anastomosed to the distal loop about eight inches distal to its anastomosis with the stump of the common hepatic duct. This allowed the food to progress through the small intestine without coming in contact with the hilus anastomosis. Wound closed in layers, using interrupted cotton for the fascia, and placing a drain down to the anastomosis. The postoperative course was uneventful. Eight days after operation the icterus index was 12.

When last seen (19 months after repair) she declared she was feeling fine except for troublesome epigastric pain. During the 19-month interval she had three chills with fever, but no jaundice. Stools had been cholic at all times.

**Case 2.**—Patient (No. 88494) was a white female, age 38, who entered Illinois Research Hospital April 12, 1943, with the complaint of itching and jaundice. She had a cholecystectomy performed December 26, 1941, at another hospital. A biliary fistula formed and did not close until seven months later. One month after closure of the fistula she became jaundiced. After this she had recurring attacks of jaundice.

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She had another operation at the same hospital February 26, 1943, following which she was free from jaundice for one month, after which time it recurred and remained constant until admittance to Illinois Research Hospital.

Operation for correction of the biliary obstruction was performed at Illinois Research Hospital, April 16, 1943. The entire gallbladder bed was found to be adherent to the upper edge of the first portion of the duodenum. This was freed with considerable difficulty. There were about 2,000 cc. of thick, bile-stained fluid in the peritoneal cavity. The region of the common duct was dissected out; the portal vein and hepatic artery were found, but there was no evidence of the common duct. Much fibrous tissue was found and explored but still no evidence of the common duct was made out. Finally, after exposing the hilus of the liver for a distance of about one-half to three-quarters of an inch, an opening was made in the stump of the duct, giving rise to a free flow of totally colorless "syrupy" bile. The funnel end of a vitallium tube was anchored in the duct with a purse-string suture of cotton; the other end of the tube was anchored in the end of the severed jejunum, as in Figure F, utilizing the Roux principle.

Convalescence was satisfactory. Two weeks after operation the icterus index was 30; it declined to normal several days later. When last seen, 20 months after operative repair, she said she was feeling fine and had gained 40 pounds. She had one slight chill July 4, 1944, but at no time had been jaundiced.

A roentgenogram, December 14, 1943, revealed the tube in place. After barium by mouth a few flakes of barium and a moderate amount of air were observed in the intrahepatic ducts.

Case 3.—Patient (No. 89009) was a white female, age 30, who entered the Illinois Research Hospital, May 14, 1943, complaining of acholic stools and a complete biliary fistula following a cholecystectomy performed elsewhere, February 5, 1943. Since operation patient also complained of pain in the right upper quadrant, loss of 25 pounds in weight and extreme weakness. There had been no jaundice previous to this operation. Laboratory examination at entrance revealed a 3-plus cephalic flocculation test, an icteric index of 117, and a red blood count of 3.7. On June 28, 1943, a celiotomy was performed but abandoned before any reparative procedure could be undertaken, because of severe hemorrhage from a tear in the liver. She recovered satisfactorily except for an increased loss of weight. She was discharged for correction of this malnutrition but returned November 11, 1943, with an acute liver abscess, which was drained as an emergency operation. During her convalescence she also developed an empyema, which required a thoracotomy. She recovered slowly and was discharged to allow improvement in her condition before the reparative operation.

Operation was performed for repair of the defect on July 10, 1944. Incision was made through the old scar dissecting out the biliary fistula which was traced down to the opening of the common hepatic duct at the hilus of the liver. No remnant of the common duct could be found except this opening at the hilus of the liver. The funnel end of a vitallium tube was anchored with a purse-string in the duct opening at the hilus and the other end implanted into the cut end of the jejunum, as shown in Figure 4. A piece of rubber tubing three inches in length was attached to the end of the vitallium tube to prevent the tube from slipping out of the end of the intestine. This arm of jejunum was brought up to the common duct under the colon. Two folds in the jejunum were made in an attempt to duplicate valves. Wound closed with through-and-through sutures. Three Penrose drains left in place. The post-operative course was uneventful and afebrile. The icterus index was 11 at time of discharge on the 14th postoperative day. Culture of bile made at operation revealed *alpha Streptococcus*, *B. coli*, *B. hemolyticus Streptococcus* and diphtheroids.

Patient has gained 40 pounds since operation. Up until December, 1944, she had eight chills with fever but no jaundice. When last seen, in March, 1945, she had had no chills for four months and was feeling fine. However, she has a draining sinus

which is probably caused by a chondritis or osteomyelitis secondary to the liver abscess. A roentgenogram, taken in March, 1945, revealed no tube, indicating that it had passed.

**Case 4.**—The patient was a white female, age 36, who gave a history of having had a cholecystectomy performed in an hospital elsewhere, in January, 1943. Within a few days she became jaundiced and had clay-colored stools. Jaundice persisted constantly for several weeks, after which time she had another celiotomy. At this time, a dense mass of fibrous tissue was found in the region of the common duct, but no trace of the duct itself could be found. Jaundice and clay-colored stools persisted.

*Operation* for repair of the duct obstruction was performed in May, 1943. A moderate number of adhesions were encountered between the surface of the liver and contiguous organs. Separation of these adhesions down to the posterior peritoneum revealed no trace of the common duct. Aspiration of the only tubular structure in that neighborhood yielded blood, indicating that it was the portal vein. The hilus of the liver was then explored and a slightly bulging point aspirated; thin, slightly bile-stained fluid was obtained. This stump of common duct was opened and the funnel end of a vitallium tube anchored in place with a purse-string suture of silk. The other end of the vitallium tube was anchored in the cut end of the jejunum, as in Figure 6. An attempt was made to create valves in the arm of jejunum by making two folds of the intestinal wall with interrupted silk sutures. The arm of jejunum was brought up to the hilus through an opening in the mesocolon. Wound closed leaving a drain in the upper end. Convalescence was uneventful. Stools became cholic and remained so up to date. Patient had a few mild chills soon after the plastic repair, but declares that she feels better now than she did before any of her operations, including the first one.

**Case 5.**—Patient (No. 99027) was a white female, age 39, who entered the Illinois Research Hospital complaining of jaundice and clay-colored stools. She gave a history of having had a cholecystectomy, in March, 1943, at a hospital elsewhere. The gall-bladder was filled with many stones. She had a stormy postoperative course due to wound infection and rupture of the incision. About four months after the cholecystectomy patient noticed jaundice which became progressively worse up until time of entrance in Research and Educational Hospital. Itching and clay-colored stools likewise were present. Examination revealed deep jaundice. A large mass occupied the entire left upper quadrant extending to the iliac crest; it was presumably an enlarged spleen. Liver edge was palpable 4 cm. beyond costal margin. Stools were acholic. The icterus index was 78, and the cephalin flocculation 3 plus. The N. P. N. was 24 mg. per cent and the A/G ratio 3.4/2.6 mg. per cent. The red blood count was 2.5, requiring several transfusions before patient could be considered operable.

*Operation* was performed for correction of the duct obstruction, April 20, 1944. Incision was made through the old scar. The abdominal wall was unusually vascular. After entering the peritoneal cavity numerous adhesions were encountered which likewise were very vascular. This made it appear definite that there was a portal hypertension, supported by the fact that the spleen was enormously enlarged. The liver itself was markedly enlarged, dark red in color and congested. Perhaps 40 minutes were consumed dissecting colon, duodenum, etc., away from the hilus of the liver before we could obtain exposure in that area, which was badly "frozen," and all structures were covered with so much fibrous tissue that landmarks were very poorly visible, if at all. No trace of a common duct could be found. There were two large structures going toward the hilus of the liver. They were poorly defined because of fibrous tissue, but aspiration yielded blood, indicating that they were veins, although the dual structure at this point was difficult to explain except by anomaly of premature branching of the portal vein. Both of the venous structures were somewhat indurated, suggesting that there was, or had been, a thrombosis, although the aspiration of blood indicated that they were recanalizing. By continued aspiration we encountered an area in the hilus of the liver where bile-stained fluid was obtained. This was slightly to the right

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of the two veins and artery, but aspiration directly to the right of the area likewise yielded blood. This area leading to the hepatic duct was apparently entirely surrounded by large veins, but by utilizing unusual care we got into this cavity without damaging any of the branches of the portal vein. Further dissection downward toward the duodenum revealed a thin, small structure which was obviously the remnants of the common duct. It was filled with plastic exudate, and appeared now to be entirely blocked. The mucosal surface appeared to be destroyed, and it seemed likely that it would ultimately, quite definitely be completely stenosed. It appeared then that we would have to make an anastomosis of the hilus of the liver to a loop of intestine. In our endeavor to dilate the opening in the hepatic duct, we damaged a sizable branch of the portal vein within the liver which made it impossible to continue. We, therefore, decided to pack this area, and if bile began to flow postoperatively we could go back in several days later, and perform the anastomosis. Accordingly, a small gauze pack was placed firmly against the hilus of the liver, and the wound closed around a drain left in the upper portion.

The pack was removed on the third day. This was followed by a gush of bile, which drained constantly making a second operation seem justifiable.

*Second Operation* was performed, April 26, 1944, hoping to be able to complete the anastomosis of the hilus to a loop of intestine. Since insufficient time had elapsed to allow formation of adhesions, we obtained exposure of the hilus of the liver without much difficulty. The opening of the common hepatic duct at the hilus was dilated and the funnel end of a vitallium tube anchored in with a purse-string suture of silk. We implanted the other end in the severed end of the jejunum, after the Roux principle as illustrated. The arm of the jejunum was brought up through an opening made in the mesocolon. The liver was so swollen and congested that it seriously obscured our field at the hilus, and the vitallium tube was actually too short to bridge across the area between the mucosal surface of the hepatic duct and the mucosal surface of the intestine. We accordingly spliced a rubber tube two inches long onto the end of the vitallium tube. This allowed us to anchor the end of the intestine against the hilus of the liver without any possible danger of the vitallium tube slipping out of the intestine. We attempted to produce a valve in the arm of jejunum by infolding the wall acutely into the lumen with several interrupted cotton sutures. The wound was closed in layers around a Penrose drain in the upper portion.

The patient's convalescence was stormy because of atelectasis and a stubborn distention which responded poorly to intestinal decompression.

The stools became cholic, but the splenomegaly and jaundice persisted. The spleen, in fact, was enlarged much more now than at the time of operation, and an ascites had developed. The entire picture of splenomegaly, portal hypertension and ascites, strongly suggested the coincidental development of Banti's syndrome. Since this is the only case of its type in our series we assume the clinical picture is coincidental unless it is related to the portal thrombosis which we are certain was present even at the time of the first of the two reparative operations.

*Case 6.*—Patient (No. 83352) was a white female, age 34, who entered Research and Educational Hospital June 10, 1942, with a history of having had a cholecystectomy December 30, 1941, at a hospital elsewhere. Considerable bleeding around the junction of the cystic and common duct required the insertion of an artery forcep, which was left on for a day or two. A few days after operation an external biliary fistula developed. Considerable purulent discharge likewise drained from the fistula for several days. Shortly thereafter jaundice accompanied by frequent chills with fever developed.

*Operation* for correction of the duct obstruction was performed at Illinois Research Hospital, June 13, 1942. Numerous adhesions were present. No trace of the common duct was found. Accordingly, a loop of jejunum was brought up through an opening in the mesocolon and attached to the hilus of the liver over a vitallium tube, the funnel end of which was anchored in the stump of the common hepatic duct with a purse-

string suture of silk. Illustrated. Wound closed around a Penrose drain in the upper portion.

Convalescence was uneventful. Following discharge from the hospital she was symptom-free for two years, after which time she began to have frequent chills accompanied with fever. On one occasion she developed slight jaundice which disappeared in a few days. A roentgenogram showed the tube in place, but administration of barium by mouth revealed a massive reflux of barium into the intrahepatic bile ducts.

COMMENT: Since the tube is still in place (according to the roentgenogram), thus, preventing any stenosis from developing at the anastomotic line, the only explanation for the chills appears to be a cholangitis, which could readily be caused by the reflux of intestinal contents into the intrahepatic bile ducts. Another operation to interrupt the proximal limb of the jejunal loop and perhaps construction of folds in the distal descending loop of jejunum for valves, appears justified, and has been advised.

Case 7.—Patient (No. 81941) was a white female, age 38, who entered Illinois Research Hospital, March 15, 1938, complaining of jaundice and severe itching. She had a cholecystectomy performed in May, 1935, at an hospital elsewhere. She remained well for five months, after which time she developed epigastric pain, nausea, vomiting and, later, jaundice. In February, 1936, celiotomy was performed at another hospital, at which time the duodenum was anastomosed to the stump of the common hepatic duct at the hilus of the liver, over a rubber tube. Several months later she passed the rubber tube and again became jaundiced. At Illinois Research Hospital she had another anastomosis performed, April 6, 1938, between the duodenum and stump of the common hepatic duct over a rubber tube. Eight months later, jaundice and other symptoms recurred. On January 17, 1941, the same operation as described above was again performed. However, several months later symptoms recurred. On March 18, 1942, we sutured the end of the common hepatic duct at the hilus to a loop of jejunum over a rubber tube. The loop of jejunum was brought up to the hilus through an opening in the mesocolon; an anastomosis between the two arms of the jejunum was made two or three inches inferior to the mesocolon, hoping to shunt the food away from the suture line at the hilus. Patient was well until five months later, when she passed the rubber tube, after which she became jaundiced and had numerous chills with fever. On March 31, 1943, she was operated upon again and a vitallium tube placed between the stump of the common hepatic duct and loop of jejunum. Roentgenologic studies following barium by mouth 1.5 years after the reparative operation revealed the intrahepatic ducts filled with barium. A few weeks later a roentgenogram revealed the absence of the vitallium tube; which had obviously been passed. She remained entirely well for two years, then suddenly developed severe chills with fever. After 12 days observation, and unsuccessful treatment with penicillin and sulfadiazine, we operated upon her, interrupting the proximal loop (which was allowing reflux of food) hoping that the infection still was limited to a cholangitis and had not progressed to multiple abscess formation. However, the infection had apparently reached the hopeless stage since she died a few days later. Autopsy revealed multiple abscesses of the liver.

Case 8.—Patient (No. 82624) was a white female, age 54, who entered Research and Educational Hospital, April 28, 1942, complaining of jaundice and clay-colored stools. She gave a history of having had a cholecystectomy in April, 1940, at an hospital elsewhere. Before cholecystectomy patient had epigastric pain, nausea, vomiting, belching and bloating, but no icterus. She developed jaundice on the second postoperative day, which became progressively worse. She was reexplored two weeks after cholecystectomy; an external biliary fistula was established which drained for three months. Following this, the wound healed. However, recurrent jaundice occurred with chills, fever, pain and swelling in right upper quadrant. These symptoms would disappear

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when external biliary fistula recurred. Attacks occurred one to three times monthly and lasted for two to five days.

*Operation* was performed at Illinois Research Hospital for correction of the duct obstruction, May 4, 1942. There were numerous adhesions over the entire upper quadrant following the previous operations. The gallbladder was gone. We followed the liver edge from the outside, working medially. We came to an attachment of the colon with the hilus of the liver. When this was cut we noted a small opening in the colon suggesting there had been a fistula between the colon and the common duct. Drainage of a small amount of bile from the liver side of this attachment offered further support that there was a fistula between the common hepatic duct and colon. It was, of course, impossible to determine what the previous operations had to do with this fistula. We tried to find the distal end of the common hepatic duct or any portion of the common duct. We were unsuccessful. We then opened the duodenum low in its second portion to see if we could find the sphincter of Oddi, and probe the ducts from the duodenal side. After several minutes exploration we were unable to find the ampulla of Vater. We then closed the opening in the duodenum and decided to bring up a loop of jejunum and perform an anastomosis between it and the hepatic duct at the hilus over a vitallium tube. We inserted the funnel end of a small-sized tube in the hepatic duct and closed the opening around it with a purse-string suture of silk. We then made an opening in the loop of jejunum and inserted the other end of the tube. We then established an anastomosis between the two loops of jejunum about six inches away from the anastomotic line. This shunted the food away from the anastomosis between the duct and the jejunum. We had brought the jejunum up through a hole in the mesocolon. The wound was then closed, leaving a drain in the upper portion.

Convalescence was uneventful and the patient was free from symptoms for a few months. However, after that period she developed recurrent attacks of chills, fever and icterus. Roentgenologic studies, January 25, 1944, following barium by mouth showed a barium fill-up of the intrahepatic ducts. We, accordingly, decided to operate upon the patient again, and interrupt the proximal loop of jejunum hoping to exclude intestinal content from the biliary ducts.

*Second Operation.*—January 28, 1944: The anastomotic opening between the two loops of jejunum just under the mesocolon was found to be ample. We then resected about three inches of the proximal loop, thus, interrupting the bowel so that food could not go around the normal channel past the hilus of the liver. To further prevent influx of food upward toward the vitallium tube and hilus of the liver, we made a valve in the distal or descending loop. The valve in the intestine was made by making a horseshoe-shaped incision with the base toward the hilus and inverting this flap so that there would be a valve-like mechanism preventing food from going upward, but allowing bile to drain downward. When the opening was closed we were a bit concerned as to whether or not our valve flap was too large, but thought we would take the chance since we knew a certain amount of atrophy and contracture of the flap would take place. Culture of bile taken at the time of operation from the intrahepatic ducts revealed *Staphylococcus albus*, *B. proteus*, *B. coli* and *gamma Streptococcus*.

Postoperatively, she developed a biliary fistula which appeared to include a small quantity of intestinal content, but no food particles. Apparently we had created a temporary obstruction to the bile with our large flap. However, after 10 or 12 days the fistula closed and the wound healed.

When last seen, in April, 1945, she was feeling fine and had had no symptoms since her last operation 15 months previously. However, a roentgenogram, February 8, 1945, revealed no vitallium tube; apparently it had passed. No barium refluxed into the intrahepatic bile ducts but a small quantity of air was visible.

*Case 9.*—Patient (No. 86931) was a white female, age 56, who entered the Research and Educational Hospital, January 29, 1942, complaining of jaundice, chills and acholic stools. At another hospital she had had a cholecystectomy in May, 1938. Patient was



jaundiced prior to cholecystectomy which did not ameliorate the jaundice. Icterus became more pronounced with loss in weight, *etc.*, later. In January, 1940, she had another operation at which time no common duct could be found. A catheter was sewn into the common hepatic duct at the hilus to create an external biliary fistula. Convalescence was stormy. Six months later she was operated upon again (likewise, at another hospital) and a T-tube sutured in place between the duct at the hilus and a loop of jejunum. Recovery was slow, but after a few weeks the jaundice disappeared. In November, 1940, the T-tube was removed because of discomfort. She remained well until July, 1941, after which time jaundice, chills, fever and malnutrition returned.

Examination upon admission to Illinois Research Hospital revealed jaundice and moderate malnutrition. The red blood count was 4.3.

*Operation* was performed for correction of the obstruction, February 4, 1942. Numerous adhesions were present, which after separation revealed a loop of jejunum attached to the hilus of the liver, where it had been placed at a previous operation done elsewhere. There was an anastomosis between the two loops of jejunum down low, so that food could pass without going around the loop over the duct anastomosis. Cutting across the anastomosis between the duct at the hilus of the liver and the jejunal loop revealed a total stricture of the common duct at this point. Bile began to flow freely. A rubber tube, two inches long and size No. 18, was inserted at this anastomotic junction and anchored with two stainless steel sutures and two of cotton against the hilus, hoping to keep it in position. The wound was closed around a drain in the upper portion. The postoperative course was uneventful. Patient remained symptom-free for only seven months and returned with chills and fever.

*Second Operation.*—January 15, 1943: A small incision was made at the junction of the loop of jejunum and the duct at the hilus and a vitallium tube was inserted, with the funnel end in the bile duct and the other end in the jejunal lumen. The rubber tube had been passed. A drain was left in the upper end of the wound.

She remained symptom-free for about six months, and again returned with jaundice, chills and fever. However, her stools were always cholic, indicating that there was a patent opening for entry of the bile into the intestinal tract. A roentgenogram following oral administration of barium revealed a free reflux of barium into the intrahepatic bile ducts; this tended to confirm our suspicions that the cause of the chills was a cholangitis.

*Third Operation.*—October 2, 1943: Interrupting the ascending or proximal loop of intestine, but not making any valves in the descending or distal loop. The jaundice, chills, fever and anorexia disappeared in a week or so and have remained absent to date (March 6, 1945) with the exception of three or four chilly sensations she had in October and December, 1944. However, in the meantime she had developed a diffuse and rather severe arthritis along with certain cardiac symptoms including precordial pain, dyspnea and ankle edema. There is no evidence that these symptoms are related to her biliary difficulties. A roentgenogram following oral barium still reveals a reflux of barium into the intrahepatic ducts, resulting from our failure to place valves in the remaining arm of jejunum; however, the interruption of the proximal loop has apparently minimized the reflux of intestinal content into the bile ducts sufficiently to prevent infection, *i.e.*, cholangitis.

*Case 10.*—Patient (No. 85338) was a white female, age 67, who entered Illinois Research Hospital first in November, 1942, with the history of jaundice, acholic stools and a biliary fistula since a cholecystectomy performed in August, 1942, at a hospital elsewhere. Shortly before the patient entered Illinois Research Hospital she developed a right femoral thrombosis, with pronounced edema of the entire extremity. Anorexia, weakness and malaise were so pronounced and responded so feebly to therapy that we sent her home for a short time hoping that home environment would improve her.

However, at a second admission, late in December, 1943, the patient was still found to be a poor surgical risk; anorexia and weakness were persistent. Her condition improved but little, with transfusions, forced feeding and parenteral feeding of glucose

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and amino-acids. When it appeared that we had obtained as much improvement as possible we subjected her to a celiotomy (January 8, 1943).

*Operation.*—No common duct was found except for a stump of the common hepatic duct at the hilus of the liver to which the biliary fistula led. We, accordingly, brought up a loop of jejunum through an opening in the mesocolon and anastomosed it to the short stump of the common duct over a vitallium tube; an anastomosis was made between the two loops of jejunum inferior to the mesocolon.

Convalescence was stormy and complicated by a wound infection. The blood protein became reversed (alb. 2.4, glob. 3.3 Gm. per cent) and the patient was apathetic, indicating the probable presence of a severe hepatic insufficiency. The weakness and malaise increased in spite of transfusions, *etc.*; and she died three weeks after operation. At autopsy, the most significant finding was an extensive cellular necrosis of the liver, although a small subphrenic abscess was also present.

*Case 11.*—Patient (No. 96826) was a white female, age 34, who entered the Research and Educational Hospital, September 8, 1943, complaining of jaundice and pain in the right upper quadrant. She had had a cholecystectomy and choledochostomy performed in January, 1943, at a hospital elsewhere. She was well for three months, after which time she developed itching and jaundice and a recurrence of her pain in the right upper quadrant. Examination revealed jaundice (icterus index 26) and acholic stools.

*Operation* was performed at Illinois Research Hospital for repair of the duct obstruction, October 1, 1943. Numerous adhesions were present in the right upper quadrant; after their separation a bulging stump of proximal common hepatic duct, measuring 2 or 3 cm. long, was found. A stricture was present at the terminal end of this stump. Further dissection revealed the terminal end of the common duct, with a defect of about 1 or 1.5 cm. intervening. A probe was placed in the distal end. It passed readily down to the duodenum. However, we could not be certain that it passed into the duodenum. There was so much uncertainty that I finally opened the duodenum to clear this point. We found that the probe came up against the duodenal wall, but nowhere could it be made to enter the duodenum. There was obviously a stricture at this point as well as higher up. We incised the duodenal wall over the probe, and dilated this fibrotic area. We then took the end of a catheter (size No. 16) and threaded it up into the distal end of the common duct, allowing about three inches to remain in the lumen of the duodenum. We then closed the opening we made in the duodenum and placed a vitallium tube (with a flange in the center but no funnel tip) between the two ends of the common duct at the constriction. We could not bring the two ends together without jeopardizing the blood supply, but were able to close over the defect with adjacent tissue. Wound then closed in layers, using interrupted cotton for the fascia.

Convalescence was uneventful. However, she complained of considerable epigastric pain and an occasional mild chill. It was thought that the epigastric pain was due to a ventral hernia which had developed following the first operation and had been repaired inadequately at the second operation on account of the duration of the operative work for correction of the duct obstruction. Accordingly, several months ago the hernia was repaired. The vitallium tube was found in place and covered so completely with fibrous tissue that it was not disturbed.

A roentgenogram, February 16, 1945, showed the tube in place. After barium by mouth no barium or air was noted in the intrahepatic ducts.

*Case 12.*—Patient (No. 93977) was a white female, age 64, who entered Illinois Research Hospital, April 18, 1944, complaining of jaundice and acholic stools of six months' duration, with associated pain of only mild degree. She had not had any previous operations.

*Operation.*—April 24, 1944: Celiotomy disclosed a distended gallbladder; the head of the pancreas was normal; and the distal end of the common duct collapsed. A carcinoma was present in the common duct at the junction of the cystic duct, extending up

toward the hilus of the liver but not into it. There was enough uninvolved common hepatic duct to allow us to accomplish a local resection. A segment of normal duct about one-half inch long was left on each side of the specimen. The duodenum mobilized readily, allowing us to bring up the common duct to meet the cut end of the hepatic. Exploration of the distal end of the common duct revealed a doubtfully patent outlet at the sphincter of Oddi. We opened the duodenum over the sphincter and discovered that the probe came up against the duodenal wall but there was no sphincter opening. We, accordingly, cut down upon the probe and inserted a piece of rubber tubing two inches long, upward into the terminal end of the common duct, leaving about three-quarters of an inch protruding into the lumen of the duodenum. The opening in the duodenum was then closed. An anastomosis was performed between the two cut ends of the common duct around a vitallium tube without tension. Interrupted cotton was used for the suture material. Previous exploration had revealed no metastasis anywhere. Wound closed around a Penrose drain, using interrupted cotton for the fascia.

Convalescence uneventful for few days but patient then developed a pyloric obstruction which would not subside with decompression. We, therefore, reoperated on May 18, 1944. Very dense adhesions were found in the right upper quadrant. They were so dense that we assumed dissection of the pylorus and duodenum from this mass might result only in temporary relief. We accordingly performed a posterior gastro-enterostomy.

Recovery was uneventful. Since discharge, she has had a few mild chills and one attack of jaundice, without fever, which, however, cleared after two weeks, indicating that it was not due to metastases. Since then she has had very few symptoms, although insufficient time has elapsed to determine the prognosis from the standpoint of metastases. She did not pass the rubber tubing which we had inserted upward into the distal end of the common duct until eight weeks after insertion.

A roentgenogram, February 13, 1945, showed the vitallium tube in place. After barium by mouth no barium or air was found in the intrahepatic ducts.

**Case 13.**—Patient (No. 91465) was a white female, age 34, who entered Illinois Research Hospital in October, 1943, complaining of jaundice and acholic stools which had been present before and since an operation performed elsewhere six weeks previously. The operation in September, 1943, had not relieved the common duct obstruction.

*Operation* was performed October 28, 1943, at Illinois Research Hospital hoping to correct the obstruction. A defect was found in the common duct; no proximal segment could be found, but a distal segment was isolated. The duodenum and distal end of the common duct were mobilized and distal end of the common duct sutured to the stump of the common hepatic duct at the hilus, over a vitallium tube.

A culture of bile taken at time of operation revealed *Esch. coli*, *gamma Streptococcus* and *Staphylococcus albus*. Convalescence was stormy. Fever was present, and appeared to be explained, only in part, by a wound infection which developed a day or two after operation. Signs of peritonitis developed which were controlled only to the point of localization by intravenous sodium sulfadiazine. Numerous abscesses developed. On November 8, 1943, a cul-de-sac abscess was drained; on November 15, 1943, an abscess in the left upper quadrant; on December 3, 1943, an abscess in the neighborhood of the wound, and on December 13, 1943, a liver abscess was opened. In spite of this, however, her condition became worse and she died eight weeks after operation. Autopsy revealed numerous abscesses in the liver.

**COMMENT:** The patient had had fever for several days before operation, and the usual means of treatment including the use of sulfonamides were not effective in eliminating the infection, which presumably was a suppurative cholangitis. In retrospect, it appears it would have been better not to have proceeded with the complete operation in the presence of the infection and fever; no doubt, we should have established better drainage of the bile ducts,

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with the aid of a catheter and drains, as a preliminary operation, thereby hoping to eliminate the infection before imposing the load of the entire reparative operation upon the patient. Penicillin was not then available.

**Case 14.**—Patient (No. 83167) was a white female, age 38, who entered Research and Educational Hospital May 29, 1942, with a history of recurrent attacks of icterus, clay-colored stools and cramping pain in the right upper quadrant for one year preceding cholecystectomy, performed May 7, 1942, at a hospital elsewhere. Patient has been jaundiced continually since second postoperative day; in addition, she has had itching, clay-colored stools and an external biliary fistula. The icterus index was 87. The red blood count was 3.1, and the hemoglobin 11 Gm. per cent.

*Operation* was performed at Illinois Research Hospital for a biliary fistula and obstruction of the common duct, June 4, 1942. A stricture of the common duct was found. It was not possible to bring the ends of the duct together; therefore, a vitallium tube was sutured into the duct with the funnel end inserted proximally. One Penrose drain was placed down to the vitallium tube; and the wound closed in layers.

Recovery was good, with practically no complaints except for one attack of jaundice associated with acholic stools two years postoperatively. This attack of jaundice lasted for one week, but subsided completely; and patient has had no difficulty since.

A roentgenogram, December 20, 1944, showed the tube in place. After barium by mouth no barium or air was found in the intrahepatic ducts.

**COMMENT:** The chief advantage of vitallium tubes in the operative repair of strictures of the common duct is to prevent a recurrence of the stricture which so commonly happened after the old conventional method of repair. Commonly, a rubber tube was used but there is a great deal of evidence supporting the fact that rubber is much more of a foreign body than is vitallium. In the repair of complete absence of common duct, an anastomosis of the stump of the common hepatic duct at the hilus of the liver to the functioning duodenum, with implantation of a vitallium tube to maintain patency of anastomosis, would appear to be the simplest type of repair. However, the authors have been of the opinion that the food stream would sooner or later dislodge the vitallium tube which would naturally be protruding into the lumen of the functioning intestine. Accordingly, we have not used this type of repair. It appears to us that one of the greatest advantages of the tube would be in its continued presence at the anastomotic line, thus, eliminating stricture formation. However, as will be discussed below, there is opportunity for reflux of food and intestinal secretions through the tube into the intrahepatic ducts which would be a source of considerable danger from the standpoint of cholangitis.

The pathologic lesion producing the chills and fever in stricture of the common duct is cholangitis. In a stricture of the common duct, with the sphincter of Oddi normally intervening between it and the intestine, obstruction would appear to be the primary factor in pathogenesis of the cholangitis. However, when correction by an operative procedure attaching the intestine directly to the duct has been performed, thus, eliminating the protective action of the sphincter, an added etiologic factor (*i.e.*, reflux of food and intestinal content) is introduced. We are convinced that on certain occasions the

reflux of food and intestinal content is more important than obstruction. For example, Figure 9 illustrates reflux of barium through the anastomosis performed between the hilus stump and the duodenum after the conventional method. The patient has had numerous attacks of chills and fever, but has never had more than latent jaundice, implying that any obstruction present is at least too insignificant to produce jaundice. It seems obvious that if the opening was large enough to allow reflux of barium, it should be large enough to allow bile to flow through it, but, likewise, it would be large enough to allow reflux of food and intestinal secretions up into the liver with consequent development of cholangitis. It might be claimed that the chills and fever in the case just mentioned were due to partial obstruction. However, if partial obstruction was the primary factor in the production of cholangitis of this type it would appear that we should have chills and fever more consistently in patients with obstruction (partial or complete) of the common duct by stone. Although chills and fever do occur in obstruction of the common duct by stone the condition is, nevertheless, relatively uncommon. In our opinion, the sphincter of Oddi represents a protecting mechanism in a common duct obstructed by stone. Accordingly, it would appear that we should attempt to create the effect of the sphincter of Oddi in our repair of strictures of the common duct, although we grant that it is impossible to duplicate it exactly. The logic of this statement is supported by the fact that in our small series we had good to excellent results in all patients in whom we were able to preserve the function of the sphincter of Oddi.

Another factor which convinces us that reflux of intestinal content is important in the development of cholangitis is the poor result in four patients surviving the operation of anastomosis of the stump of the common hepatic duct at the hilus to a loop of jejunum, as in Figure 7. It is true that two of these patients had good results for a year or two, but, ultimately, chills and fever without jaundice recurred. Examination during a gastrointestinal series revealed that there was a reflux of barium through the vitallium tube into the intrahepatic duct in all four cases. Although we had performed a short-circuiting anastomosis between the two loops of jejunum at some distance from the anastomosis, a great portion of the intestinal stream continued to follow the normal channel rather than go through the anastomotic stoma. Three of these patients have been reoperated upon, and the proximal limb of jejunum interrupted, thereby preventing gross reflux. Two of these have had no chills since this operation, the third was just operated upon and insufficient time has elapsed to determine results.

In our experience with the two types of jejunal attachment we are, therefore, convinced that the attachment of a single arm of jejunum, after the Roux principle, to the hilus stump is a much better operation than anastomosis of the duct stump to a loop of jejunum. This arm of jejunum must be at least 24 inches long, since we have already learned that regurgitation can take place in short loops, particularly if valves or baffles have not been created.

We have had so many instances of cholangitis following various types of plastic operation upon the common duct that we have come to fear it more than any other complication. It has long been known that cholangitis is a serious complication, insofar as multiple abscesses of the liver are so apt to develop. We have sufficient evidence that cholangitis of the type presented in this kind of obstruction is of bacterial type, because cultures made of bile on every occasion when we have taken them at the operating table in these stricture cases have been positive. Invariably, the flora is a mixed one, consisting primarily of *B. coli*, streptococcus and staphylococcus. One of these patients developed an uncontrollable cholangitis followed by multiple abscesses of the liver, and died a few weeks after operation. In our limited experience, cholangitis has been uncommon in plastic repair of the duct when it has been possible to preserve the function of the sphincter of Oddi; it has been relatively uncommon when sufficient common hepatic duct is available to transplant into a loop of intestine (usually duodenum) as we have done in stricture due to pancreatitis, and resection of the head of the pancreas for carcinoma, not herein reported. However, it has been encountered frequently in certain types of operation when the common as well as common hepatic duct were missing.

We are not yet convinced that the vitallium tube needs to stay in permanently, although it appears desirable. The flange on the shaft of the tube was placed there primarily to prevent the tube from slipping out of position. The flange and the funnel exert a definite influence in maintaining position of the tube, but of the 14 tubes implanted by us, three became dislodged and were passed. If the tube remains in for several weeks or months and is then passed, we believe that the anastomotic opening must be sufficiently large to prevent significant stricture formation. Two of the patients in whom the tube was passed are completely free from symptoms of cholangitis, but only after we interrupted the jejunal loop so that reflux of barium, and presumably food, into the intrahepatic ducts could not take place. The third patient who lost the tube was one who was having reflux of barium, and presumably food, into the liver following the less desirable operation of anastomosing the hilus stump to a loop of jejunum. She developed serious chills, and later died, but we do not believe the passage of the tube had anything to do with this since reflux of food into the liver was taking place and would have done so even if the tube had remained in place.

#### SUMMARY AND CONCLUSIONS

We have reviewed our experience with 23 patients with stricture or absence of the common duct, including two cases of carcinoma of the common hepatic duct. In the repair of these defects we utilized implantation of a vitallium tube in 14 cases except for indefinite fibrous bands. In ten of the 14 we were unable to find any trace of the common duct. In these ten cases we anastomosed the stump of the common hepatic duct to a single arm of the jejunum (utilizing the Roux principle) in five instances, and anastomosed the

duct stump to a loop of the jejunum in five instances. In general, the results were good to excellent in patients having anastomosis between the duct stump and arm of jejunum. On the contrary, the results were poor in the cases in which we anastomosed the duct stump to a loop of jejunum which allowed regurgitation of barium, and presumably food, in spite of an anastomosis, which we had performed between the two loops at some distance from the anastomosis with the duct. Interruption of the proximal arm of jejunum, which was presumably allowing the reflux of food through the tube or duct anastomosis into the liver, in general, has obliterated the recurrent chills and fever. Obstruction unquestionably is an important factor in the development of cholangitis with chills and fever in the failure of plastic operation upon the common duct. However, *prevention of obstruction by the use of a tube*, in our experience, *did not prevent the occurrence of chills and fever unless we prevented reflux of food by operative procedure*. We have come to the definite conclusion, therefore, that the best operation in the type of patients in which no common duct can be found, is anastomosis of the stump of the hepatic duct to a single arm of the jejunum which is at least 24 inches long and the walls of which have been folded to produce valves or baffles.

In four patients, the terminal end of the common duct was found, thereby allowing us to preserve the sphincter of Oddi. Although one of these patients died following operation, the other three had good to excellent results. We attribute this largely to the fact that the sphincter of Oddi, with its normal function, prevents reflux into the duct.

In the 14 cases we had two operative deaths, constituting a mortality rate of 14.3 per cent. This can be lowered appreciably if we do not operate upon patients who are known to be very poor risks. We knew that one of the two patients who died was an exceedingly poor risk, but since restoration of bile to the intestinal tract seemed to be the only hope of obtaining recovery we subjected her to operation.

In our opinion, the vitallium tube has a definite place in reconstruction in strictures and absence of the common duct, but primarily in the patients in whom no common duct whatsoever can be found, and in the group in which the common hepatic duct cannot be found.

We believe that in local strictures the first operation should consist of anastomosis of the two ends over the arms of a T-tube inserted a short distance below the line of suture; if a stricture forms at the site of anastomosis then a vitallium (or tantalum) tube should be implanted later.

Cholangitis is sufficiently infrequent following implantation of a stump of common duct into the intestine to justify this procedure without use of a tube; if cholangitis does develop, consideration should be given to a second operation and use of a tube. However, whenever a tube is used it should be implanted into a nonfunctioning single arm of jejunum (as in the Roux procedure) to prevent reflux of food and prevent the food stream from dislodging the tube.

We have had opportunity to observe a few tubes after they had been in

place for a year or two, but in none of those seen was there evidence of corrosion or precipitation of bile salts on the wall of the tube.

We have not used tantalum, but this metal should have advantages over the alloy vitallium, insofar as it is pliable and can be bent or cut at any desired length; however, a flange or funnel end, or both, would be necessary to maintain the tube in position.

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# ADVANCED CARCINOMA OF THE EXTRAHEPATIC BILE DUCTS: CHOLEANGIOCHOLECYSTOCHELEDOCTOMY\*†

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EXTENSIVE INVOLVEMENT of the extrahepatic biliary tract by carcinoma is one of the most hopeless situations confronting the surgeon. The anatomic relationships of these ducts renders impossible a wide excision of the growths, and operations in this region are difficult because of the portal vein and hepatic arteries which are in the field, and are often partially or extensively surrounded by neoplasm. The subject of carcinoma of the extrahepatic bile ducts was thoroughly reviewed up to 1940, by Stewart, Lieber, and Morgan. A critical analysis of the reports in the literature, most authors reporting one or two patients, showed that surgical therapy was instituted in 50 cases. The ultimate mortality rate was 98 per cent, the fate of one patient remaining unrecorded. The immediate postoperative mortality was 68 per cent. Table I is a summary of statistics from this study:

TABLE I  
SUMMARY OF 50 CASES OF EXTRAHEPATIC BILE DUCT CARCINOMA

	Carcinoma Hepatic Duct	Carcinoma at Confluence of Extrahepatic Bile Ducts	Carcinoma Common Bile Duct
No. of cases treated surgically.....	21	21	8
Avg. survival.....	6.5 mos.	7.2 mos.	2.2 mos.
Avg. survival with "medical" treatment.....	8.2 mos.	4.6 mos.	4.4 mos.
	(12 patients)	(26 patients)	(13 patients)

In eight case reports<sup>2-6</sup> of advanced carcinoma of the extrahepatic biliary tract in the more recent surgical literature simple exploration with attempted drainage was carried out in five instances, with average postoperative survival of nine days. In the remaining three instances one was discharged 48 days after drainage, one survived resection for 11 months, having received good palliation for five months, and one was well seven months after operation in which T-tube reconstruction of the common duct had been performed.

From the above results it appears that surgical intervention which in most instances was simple exploratory celiotomy, with or without attempts at drainage of the biliary tract, afforded little palliation in most instances.

In view of this pessimistic picture, a series of seven patients presenting advanced carcinoma involving most of the extrahepatic bile passages and extending into the gallbladder, and in whom there was no apparent diffuse peritoneal spread or hepatic metastases, were subjected to radical resection of these ducts and the gallbladder, sometimes with excision of liver tissue about

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the gallbladder and in one instance resection of a portion of the head of the pancreas. The purpose envisaged was to ascertain if palliation might be afforded where most, or all, of the macroscopic neoplasm was removed. Drainage by simple insertion of a catheter high in the extrahepatic biliary tract was the only other alternative, and this did not appear to be a satisfactory procedure to carry out, because incision and probing into dense tumor tissue would have been necessary and would have been difficult to perform since the ducts high in the porta were involved in a dense contracted mass.

A summary of the patients and results are as follows:

#### SUMMARY OF RADICAL OPERATION UPON SEVEN PATIENTS WITH EXTRAHEPATIC BILE DUCT CARCINOMA

Case 1.—S. P. (No. 264586), male, age 67.

Carcinoma involving extrahepatic bile ducts, gallbladder, its liver bed, and the upper right lateral portion of head of pancreas. Survived operation for one year. Icterus completely cleared; return to full-time normal activity for several months; gain in weight. Second operation performed when icterus recurred 11 months after first operation. Vitallium tube inserted, *into dense mass of recurrent carcinoma in porta*, but condition did not improve, and the patient died one month later. Necropsy not obtained.

Case 2.—S. S. (No. 250119), male, age 63. (Previously cited.<sup>7</sup>)

Carcinoma of cystic duct with invasion of gallbladder, hepatic ducts and upper common bile duct. Died 22 days after operation. Necropsy revealed that hepatic artery had been resected with the tumor; there were infarcts in the liver.

Case 3.—G. C. (No. 285731), male, age 59.

Carcinoma of extrahepatic bile ducts with invasion of the gallbladder. Died six days after operation. During operation portal vein had been opened and ligation was necessary; a segment of hepatic artery was resected with the tumor. Necropsy revealed extensive septic infarction of the liver.

Case 4.—S. B. (No. 344040), female, age 56.

Carcinoma of extrahepatic bile ducts with invasion of the gallbladder and metastatic nodule in liver adjacent to the gallbladder. Living five months after excision. Icterus completely cleared. Moderately comfortable, but gradually losing weight.

Case 5.—M. M. (No. 321201), female, age 60.

Carcinoma extrahepatic bile ducts with involvement of gallbladder. Survived radical excision three months. Icterus reduced, but not relieved. Necropsy not obtained.

Case 6.—S. C. (No. 326441), female, age 72.

Carcinoma extrahepatic bile ducts with involvement of the gallbladder. Survived radical excision for five months. Icterus completely relieved. Moderate comfort during period of survival. Necropsy not obtained.

Case 7.—J. N. (No. 348567), female, age 49.

Carcinoma of lower common hepatic duct and upper common bile duct, with invasion of the gallbladder. Died 13 days after operation. Necropsy revealed bile peritonitis.

In general, the procedure, a choleangiocholecystocholedochectomy (Fig. 1), was as follows: Continuous spinal anesthesia supplemented by ethylene and ether if necessary.

1. High midline or reverse-L incision.
2. Aspiration of gallbladder if necessary to facilitate access to porta hepatis.
3. Dissection of the gallbladder from the liver bed and if extensively involved by carcinoma, wedge-shaped portion of liver excised with gallbladder.

cutting through the liver about .5 to 1 cm. wide of attached gallbladder. Hemorrhage from liver is controlled by large mattress sutures.

4. Application of hemostats to gallbladder and traction upon it to elevate mass in porta hepatis.

5. Isolation of lower segment of common duct behind duodenum after mobilization of duodenum and head of pancreas by incision of parietal peritoneum along the greater curvature of the duodenum.

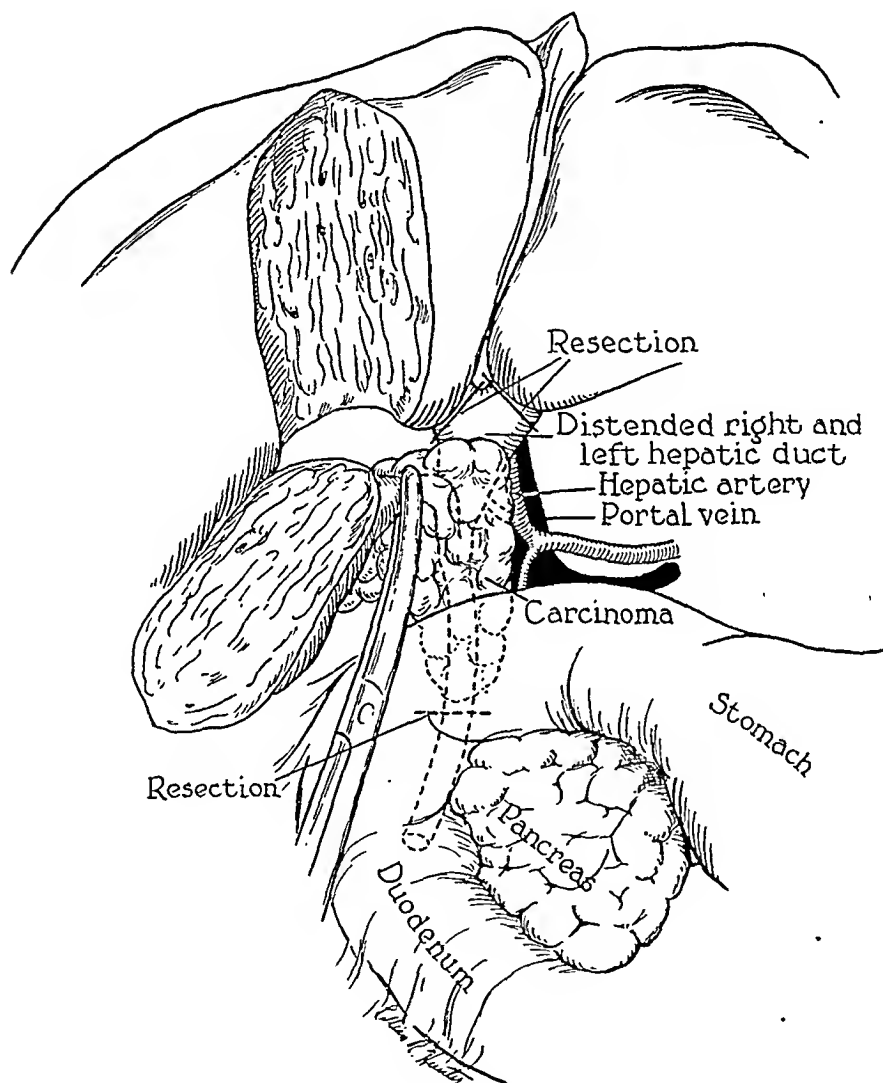


FIG. 1.—Schematic representation of resection of extrahepatic bile ducts, gallbladder and adjacent liver, for carcinoma involving these structures (Choleangiocholecystocholedochectomy).

6. Transection of common bile duct behind duodenum, and incisions into head of pancreas to mobilize portions invaded by carcinoma, if latter was present.

7. With hemostat applied to upper segment of transected common bile duct, dissection is carried out upward to free involved extrahepatic bile ducts from surrounding areolar tissue. This is the most precarious stage of the

operation since because of neoplastic invasion of areolar tissues from the ducts, the hepatic artery, and portal vein may be opened.

8. When carcinomatous ducts and attached gallbladder are freed except for right and left hepatic ducts, the latter are transected at or just beyond their emergence from the liver, and the specimen removed.

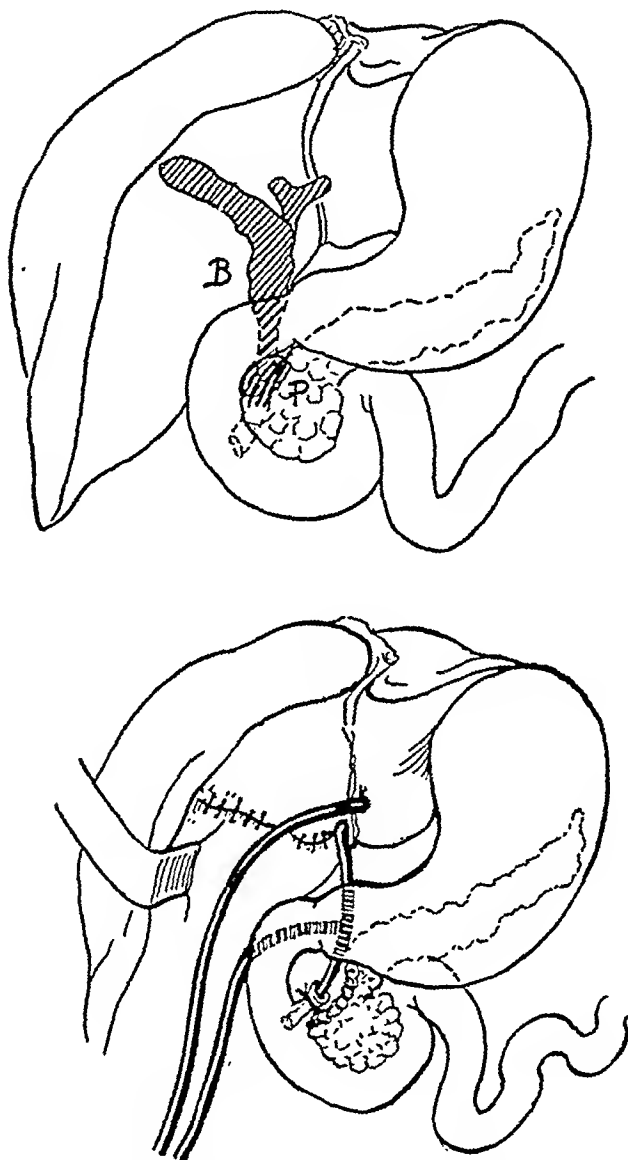


FIG. 2.—Case I S. P. (264586). A. Findings at operation—carcinoma (shaded area) involving practically entire extrahepatic biliary tract with invasion of head of pancreas. B. Termination of operation after excision of extrahepatic biliary tract, gallbladder, liver immediately surrounding it and portion of head of pancreas. T-Tube in right hepatic duct sinus and stump of common duct; urethral catheter in left hepatic duct stump. Survival 1 yr. (See text).

9. In the cases cited in this report the duodenum could not be mobilized to reach the liver, therefore, one of three procedures was carried out: (a) Two T-tubes were inserted, one in the right and one in the left hepatic duct stumps, and the lower arms inserted together in the lower stump of the common duct. (b) A T-tube was inserted between the right hepatic duct

and common duct stump, and an urethral catheter inserted in the left hepatic duct. (c) The left hepatic duct ligated, T-tube inserted between the right hepatic and common bile ducts. Soft rubber drains were placed in the right kidney fossa and the abdominal wound closed.

#### SUBSEQUENT COURSE IN PATIENTS SURVIVING OPERATION

**Case 1.**—(Fig. 2) T-tube between the right hepatic duct sinus in liver, and common bile duct stump near its termination; urethral catheter in left hepatic duct sinus. Urethral catheter came away two months after the operation. Wound healed about portion of T-tube, passing out of celiotomy incision with no discharge of bile about the tube. The latter was clamped and cut off just above skin level and left in place.

**Case 4.**—Left hepatic duct was ligated and T-tube placed between the right hepatic duct stump and stump of common bile duct. This tube came out two months after operation and was not replaced. Bile continues to be discharged from wound and patient receives bile salts by mouth. Icterus cleared.

**Case 5.**—Tube inserted as in Case 4. Copious biliary discharge about T-tube during three months period of survival.

**Case 6.**—Urethral catheters inserted in each hepatic duct stump. Practically the entire common duct was resected and lower segment ligated. Relief of icterus was the principal objective envisaged. Catheters came away two months after operation, and during remaining three months bile was discharged to the exterior. The patient received bile salts by mouth.

*Injury to the Large Vessels in the Porta Hepatis as Complications of the Operation.*—Injury to the portal vein and hepatic artery constitute the greatest hazards of the procedure. In Case 1, examination of the resected specimen revealed what was interpreted as a segment of hepatic artery constricted as a result of tumor growth about it. In Case 2, a segment of the hepatic artery was also resected, but this proved fatal in 22 days. In Case 3, both the portal vein and hepatic artery were opened and of necessity were clamped, the hemostats left in place for four days protruding from the abdominal wound and then removed. No hemorrhage ensued. At necropsy two days later, the occlusion of the portal vein and hepatic artery were confirmed. It is indeed surprising that survival was possible for six days with these vessels occluded. In Case 5 the right branch of the portal vein near the liver was accidentally opened as the resection was completed. Repair by suture was attempted but failed. Three Kocher hemostats were applied, left protruding from the wound and removed three days later without ensuing hemorrhage.

TABLE II  
RECAPITULATION OF RESULTS

Survived operation: 4 patients

Operative mortality: 3 patients (43%)

(average survival 13 days)

Of those surviving:

One lived 1 year—icterus cleared, several months of return to normal activities.

One lived 5 months—icterus cleared. Palliation.

One lived 3 months—icterus partially relieved, and pruritus completely relieved.

One living 5 months—icterus cleared but general condition deteriorating.

*Symptomatology.*—Carcinoma arising in the extrahepatic bile ducts may infiltrate along the walls of these ducts and not form localized masses which

produce biliary obstruction early in the evolution of the process. Thus, an advanced stage of the disease is attained before icterus—a cardinal sign—obtains. The principal symptomatology: icterus, pain, “dyspepsia” and marked loss in weight exhibited by the patients reported above are summarized in Table III.

TABLE III  
DURATION OF SYMPTOMS

Patient No.	Age	Icterus	Abdominal Pain	“Dyspepsia”	Loss of Weight
1.	67.....	2 wks.	0	0	0
2.	63.....	3 wks.	? 3 wks.	3 wks.	0
3.	59.....	6 mos.	0	9 mos.	40 lbs.— 9 mos.
4.	56.....	6 mos.	6 mos.	6 mos.	70 lbs.— 8 mos.
5.	60.....	7 wks.	1 yr.	?	30 lbs.— 3 mos.
6.	69.....	3 wks.	1 yr.	?	30 lbs.—10 mos.
7.	49.....	6 mos.	0	0	40 lbs.— 6 mos.

As stated, all of these patients presented advanced stages of carcinoma of the bile ducts, yet in four of the seven *icterus had been présent for only two to seven weeks*. In Case 1, who had perhaps more extensive local involvement than the others, the icterus was of the briefest duration (two weeks). The abdominal pain when present was not characteristic, neither, of course, were the “dyspeptic” symptoms. Loss in weight was appreciable varying from 30 to 70 pounds over a period of three to nine months. Possibly greater attention to unaccountable loss in weight with otherwise negative findings on physical and roentgenologic examination might lead to exploratory celiotomy earlier in the course of this type of neoplasm.

*Discussion.*—The results achieved by radical excision in seven patients with advanced carcinoma of the extrahepatic biliary ducts do not permit of alteration in the very pessimistic outlook concerning this situation. Surgical attack, as radical as conditions permitted, was carried out and survival probably not appreciably lengthened in those recovering from the operation, although icterus was ameliorated. The one exception, Case 1 (age 67) did receive appreciable palliation, living for one year, most of the time free from icterus, and well enough to return to normal full-time occupation for a few months. Possibly a greater number of patients subjected to a radical operation might afford additional instances of satisfactory palliation. Furthermore, since the possibility of a radical procedure in this region is demonstrated, its performance in the presence of more localized carcinomas might increase the opportunity for more prolonged survival in such patients. On the other hand, the frequency with which icterus may develop very late in the course of carcinoma of the extrahepatic bile ducts adds greatly to the difficulties of diagnosis in an early stage. These results are reported in the spirit expressed by Sir James Walton<sup>8</sup> who stated that a “service a surgeon can make to the progress of the art and science of surgery is to discuss the difficulties he has met with in his practice.” Furthermore, they represent what appears to be the limit of operative attack in one form of advanced abdominal cancer and what might be expected in the way of results.

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# ARTERIOVENOUS ANEURYSM\*

EXPOSURE OF THE TIBIAL AND PERONEAL VESSELS BY RESECTION OF THE FIBULA

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A NEAR DISASTER from hemorrhage of the posterior tibial vessels in the course of the excision of an arteriovenous aneurysm has prompted the approach to these vessels by the removal of the upper portion of the fibula, including the resection of the head of that bone where necessary. The rich collateral anastomosis which develops as the result of an arteriovenous communication, together with dilatation of the vessels including those which perforate the interosseous membrane, demands direct visualization of these vessels and their careful ligation and division. Otherwise the retraction of vascular channels through the interosseous membrane may result in serious or even uncontrollable hemorrhage and necessitate a second incision along the front of the leg, or the removal of the fibula in the presence of hemorrhage and at an inopportune time during the course of the operation.

While this operation has been performed primarily as an approach to arteriovenous fistulae and aneurysms of the posterior tibial vessels, it is of equal importance to realize that the same approach is necessary to reach the anterior tibial and peroneal vessels in the upper part of their course. It is often impossible to differentiate by clinical measures which of these three vessels is involved because of their close proximity to each other. No matter which vessels are involved, difficulties in exposure are similar. In fact, resection of the upper end of the fibula is probably of more importance in fistulae involving the anterior tibial and peroneal vessels near their point of origin than it is of the posterior tibial. Moreover, more than one fistula may be encountered, as was found in Case 13.

The exposure of the fibula and the method of its removal have been described by Henry,<sup>1</sup> and it is but a modification of the procedure used by him which we have followed successfully in 15 instances. The fibula is removed subperiosteally, thus, insuring continued stability of the knee joint. Moreover, the peroneal nerve which may be concomitantly injured along with the vessels is at the same time exposed and may be explored or repaired without further operative incision.

It should be stressed, however, that resection of the fibula for exposure of these vessels is necessary only in their course in the upper portion of the leg. In the lower third they are more easily reached by direct approach along the posterior surface of the tibia on the medial side of the leg.

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## TECHNIC OF OPERATIVE PROCEDURE

Continuous spinal is the anesthetic of choice. A pneumatic tourniquet is applied to the thigh but is not inflated unless severe hemorrhage is encountered. The patient is placed upon the unaffected side, with the knee slightly flexed. Incision is carried directly over the fibula beginning about two inches above the head and extending distally for a length required by the position of the aneurysm (Fig. 1B). After the skin and superficial fascia are divided at the upper end of the incision, the deep fascia is opened at the medial edge of the biceps tendon. The common peroneal nerve is exposed, and a rubber strip passed around it for aid in mobilization (Fig. 1). The division of the deep fascia is carried downward along the course of the nerve along the posterior margin of the biceps tendon. The fascial origin of the peroneus longus muscle lies directly over the groove in which the nerve passes forward across the neck of the fibula. This fascia is divided. A definite plane, the lateral intermuscular septum, between the soleus muscle posteriorly and the peroneus longus muscle anteriorly, is easily developed and, when the muscles are separated, the lateral border of the fibula is immediately exposed. By the use of sharp dissection and a periosteal elevator the periosteum can be readily stripped from the fibula and its division accomplished by means of a Gigli saw (Fig. 2A). The subperiosteal removal of the head is more difficult and is best carried out by sharp knife dissection, keeping the blade of the knife *directly* against the bone and retracting the peroneal nerve completely out of the field of incision (Fig. 1A). With removal of the head and upper portion of the fibula, the lower end of the popliteal artery with its terminal branches, namely, posterior tibial, anterior tibial, and peroneal vessels, are exposed. With the retraction of the soleus muscle posteriorly and the peroneus longus muscle anteriorly, the vessels are easily seen (Figs. 3 and 4). The resected portion of the bone is not replaced.

In excision of the fistula, the artery proximal to it is secured as the first step in the procedure. A ligature is passed around it (for safety should severe bleeding be encountered) but not tied at this time. The vessels distal to the fistula are then isolated, ligated, and divided. The proximal artery is then ligated and divided. The fistula is then removed from below upward, ligating and dividing all communicating vessels. The proximal vein is divided as the last step in the operation. *It is of utmost importance that the region of the fistula be avoided until its principal blood supply is completely controlled.*

Following removal of the insertion of the fibular collateral ligament, the question of stability of the knee joint naturally arises. Subjectively, no patient has had complaint referable to the knee joint on the operated side. Examination has failed to reveal any loss of stability. Comparison of the fibular collateral ligaments by palpation, with the ligament under stress, usually discloses as tense a ligament as on the unoperated side.

# ARTERIOVENOUS ANEURYSM

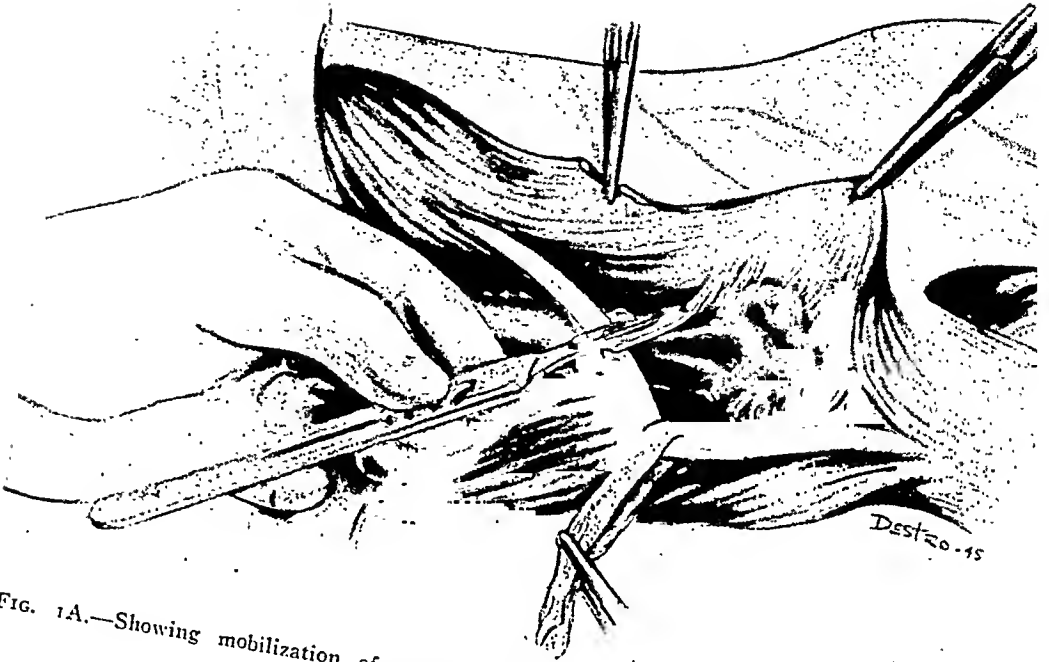


FIG. 1A.—Showing mobilization of peroneal nerve and sharp dissection of the periosteum covering head of fibula.

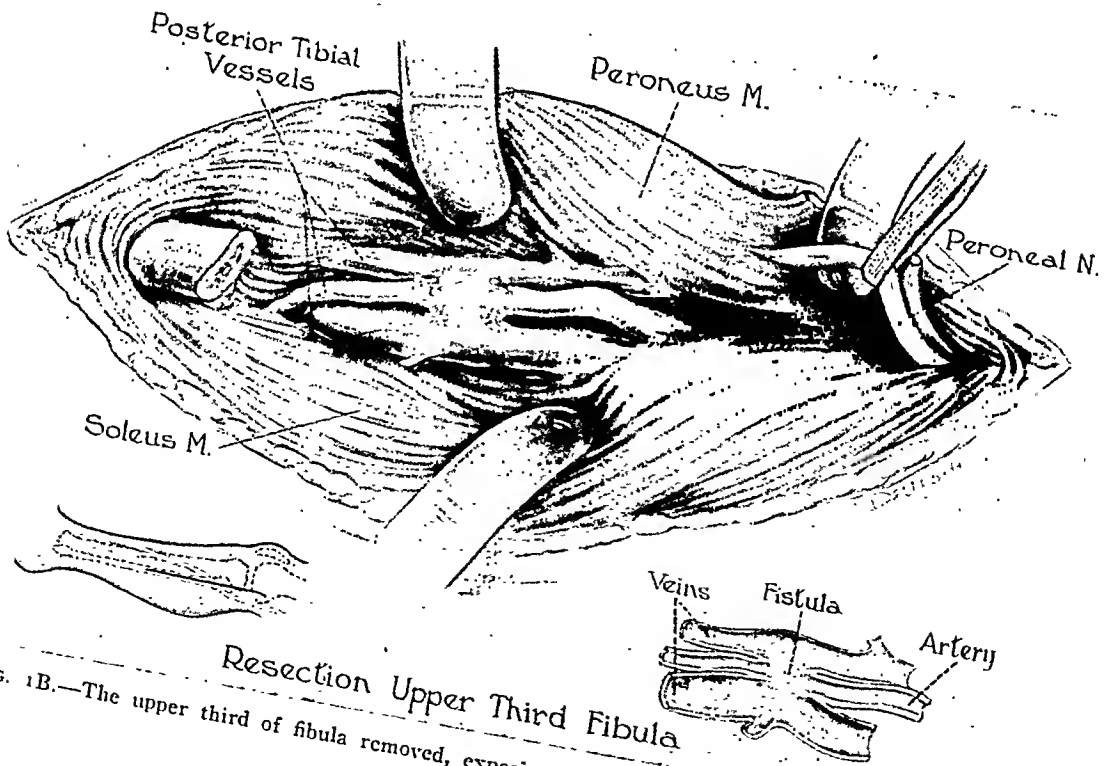


FIG. 1B.—The upper third of fibula removed, exposing fistula. Insert shows line of incision.

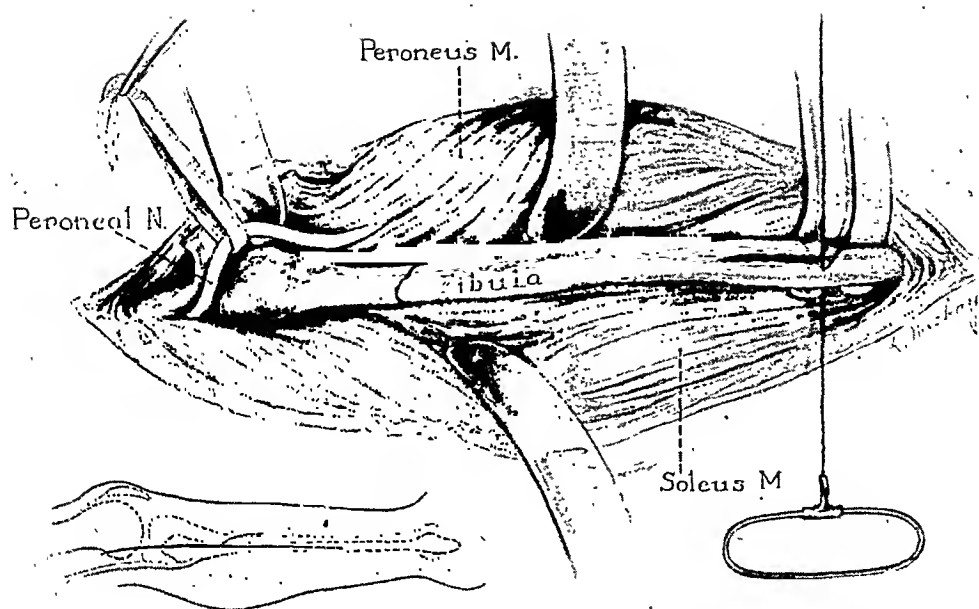


FIG. 2A.—Resection of fibula below the head.

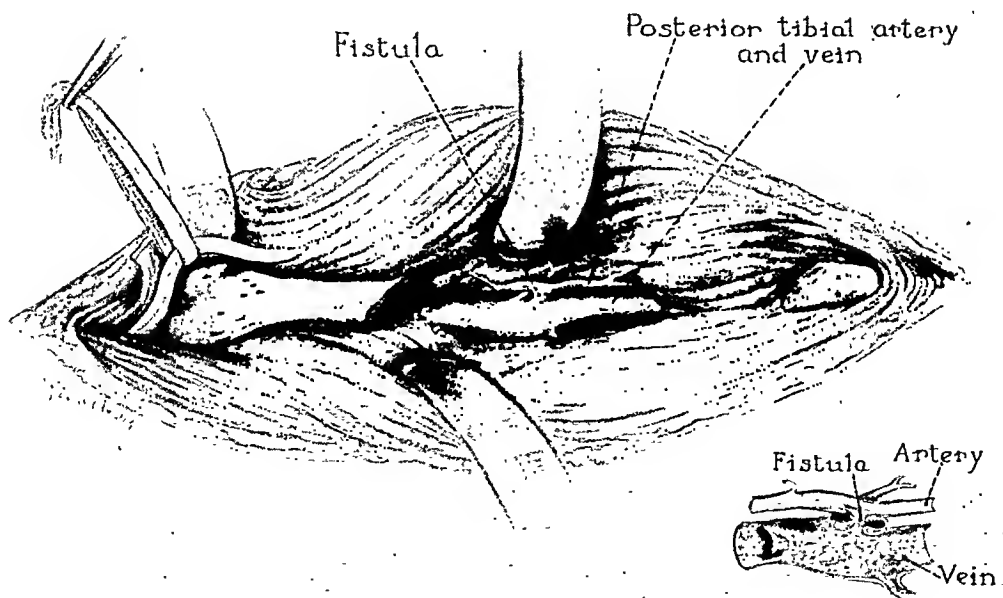


FIG. 2B.—Exposure of fistula between posterior tibial vessels.

CASE REPORTS

**Case 1.**—*A-V fistula, right posterior tibial vessels resulting from high explosive shell wound October 14, 1943. Resection of upper six inches of fibula not including the head. Quadruple ligation and excision of fistula, June 6, 1944. Recovery.*

On October 14, 1943, this 20-year-old soldier was wounded in the anterior middle portion of the right leg by high explosive shell fragment. There was little bleeding. On the same day the wound was débrided and immobilized by plaster. He was admitted to Ashford General Hospital February 14, 1944.

He complained of blueness and swelling of his right leg and foot on standing.

On examination, there was an infected wound on the anterior surface of the right leg. On elevation it became paler than the left. There was a well defined thrill and bruit, both anteriorly and posteriorly, at the junction of the upper and middle third of the leg. The bruit, which was continuous, was transmitted throughout the leg, into the foot, and upward to the middle of the thigh along the course of the vessels. Oscillations were markedly decreased at the right ankle and foot. On obliteration of the fistula by pressure the pulse rate dropped from 92 to 84 (Branham's sign). Radiography revealed no cardiac enlargement.

Drainage from the wound had ceased by May 1, 1944, and on June 6, 1944, operation was carried out. The six inches of fibula distal to the neck was resected and the fistula excised. The patient's recovery was uneventful, and there was no instability of the knee.

**Case 2.**—*A-V fistula, left posterior tibial vessels resulting from high explosive shell fragment September 17, 1943. Subperiosteal resection, upper half of fibula and excision of fistula June 28, 1944. Recovery.*

On September 17, 1944, this soldier sustained a shell fragment wound in the upper portion of the left leg, the missile entering anteriorly just below the knee. There was no wound of exit. Profuse bleeding necessitated control by tourniquet. Soon after the injury a drop foot was noted. The wound healed and the drop foot had disappeared by February 1, 1944. On March 9, 1944, at an overseas hospital, an attempted excision of the fistula was unsuccessful because the interosseous membrane interfered with proper ligation of the distal vessels. The operative note (Major John D. Martin, 43rd General Hospital) expressed the opinion that only by resection of the fibula could these vessels be secured. The proximal vessels were ligated at this time, but the bruit and thrill returned shortly thereafter, and the patient was evacuated to the Zone of Interior.

On admission to Ashford General Hospital he complained of pain in the left leg and foot, particularly after walking, and of swelling in the left leg.

There was a healed wound on the anterolateral aspect of the left leg in the upper third and a healed operative scar over the popliteal space. The left leg was considerably larger in circumference than the right. On dependency, the right toes and foot were cyanotic and on elevation there was a pallor of the left foot. The pulsation of the left dorsalis pedis artery was faint and that of the posterior tibial was absent. There was a thrill over the lower popliteal space and the upper anterior aspect of the leg and a continuous bruit, accentuated in systole, was transmitted throughout the leg and thigh. Obliteration of the bruit by pressure resulted in a diminution of the pulse rate from 72 to 60. Oscillometric readings at both popliteal levels were normal and equal. Oscillations at the left ankle were diminished and were absent in the left foot. Skin temperatures were increased over the leg in the region of the fistula and decreased at the toes. The cardiac diameter was normal.

On June 28, 1944, the upper half of the fibula, including the head, was resected subperiosteally. The fistula was easily identified because of the presence of large dilated veins. After securing the proximal and distal arteries, three large veins distal to the fistula were ligated and divided, as were numerous small communicating vessels. The fistula was removed in its entirety by ligating the vessels proximal to it as the last step in the procedure. Recovery was uneventful, and there was no instability of the knee. The patient returned to full duty as a paratrooper.

**Case 3.**—*A-V* fistula, right posterior tibial vessels, caused by high explosive shell fragment February 19, 1944. Paralysis of the right superficial peroneal nerve. Subperiosteal excision of five inches of fibula distal to the neck. Excision of fistula. Exploration of peroneal nerve July 28, 1944. Cure of fistula. No improvement in nerve function.

Following multiple shell fragment wounds, five of which involved the right leg and thigh, sustained February 19, 1944, this soldier suffered shock for which he was treated with plasma. After evacuation to the Zone of Interior some two and a half months after injury, he discovered a "buzzing" sensation in the region of the right knee, and was admitted to Ashford General Hospital July 19, 1944.

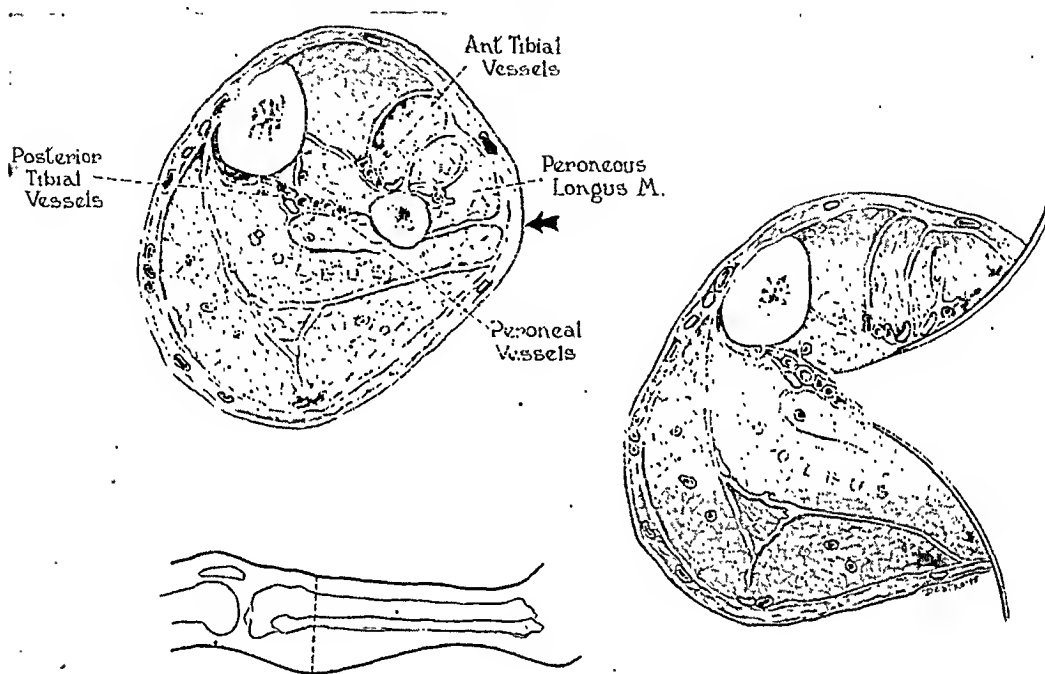


FIG. 3.—Cross-section through leg at level indicated in insert. Arrow shows point of incision through lateral intermuscular septum, with exposure of vessels after resection of fibula and retraction of muscles.

He complained of constant aching pain along the lateral aspect of the right leg and foot with alternating periods of cold and warmth in the right lower extremity and of right drop foot with anesthesia over the anterior portion of the right leg and dorsum of the right foot.

There was a considerable degree of atrophy of the right leg. Multiple wounds were present about the lateral aspect of the right lower thigh, knee, and upper leg. A large scar overlay the region just anterior to the head of the right fibula. Right drop foot was present. The right lower extremity was cyanotic. Oscillometric readings were increased at the right popliteal level and diminished at the right foot. Oscillations were normal on the left. Skin temperatures were diminished in all toes, more markedly on the right. There was a thrill over the lower popliteal space where a continuous bruit, accentuated in systole and transmitted both proximally and distally, could be heard. A striking finding was the intensity with which the bruit was transmitted along the anterior surface of the upper portion of the leg, indicating communication of the anterior vessels with the fistula. On obliteration of the fistula there was a drop in the pulse rate from 88 to 64.

At operation, July 28, 1944, five inches of the fibula distal to the neck was resected subperiosteally. The transverse fascial origin of the soleus muscle was divided, thus exposing the posterior tibial vessels in their upper portion. At this point the fistula was

located. The artery proximal to the fistula was dilated, as was the vein. The distal artery was small, but the veins were enlarged. After ligation and division of the proximal and distal arteries, a marked pulsation in the region of the fistula indicated other vessels of considerable size were entering this lesion. In the excision of the fistula several vessels, one of large size, were found to enter it through the interosseous membrane. All vessels were ligated and divided and the fistula removed in one mass.

The superficial peroneal nerve was explored and was found to be imbedded in scar tissue and to be the seat of considerable fibrosis. Recovery was uneventful, and there was considerable improvement in the nutrition of the leg, but there was no return of function in the muscles supplied by the superficial peroneal nerve. Although the heart was apparently not increased in size, there was a diminution of one centimeter in the transverse diameter following operation. He was fitted with a drop-foot brace and discharged from the service.

*Case 4.—A-V fistula, upper peroneal vessels, resulting from 25-caliber bullet June 21, 1944. Subperiosteal resection upper third of fibula and excision of fistula October 17, 1944. Recovery.*

On June 21, 1944, this soldier was struck in the left upper leg by 25-caliber bullet. He suffered a compound fracture of the upper third of the fibula. There was profuse bleeding, controlled by pressure. The wound was later débrided and the leg immobilized in plaster. On removal of the plaster six weeks later the presence of an arteriovenous fistula was discovered by a physiotherapist while giving massage. He was evacuated by air from the Pacific area and admitted to Ashford General Hospital September 15, 1944.

On admission, the patient complained of coldness and sweating of the left foot, tingling in the toes, stiffness of the left ankle and a "buzzing" sensation along the lateral aspect of the left leg.

There was a small healed wound of entry on the medial aspect of the left leg at the level of the tibial tubercle and a wound of exit on the lateral side of the leg at the junction of the middle and upper thirds. A thrill could be felt at the junction of the upper and middle thirds of the leg both anteriorly and posteriorly. A loud, harsh continuous bruit was most marked at this area and was transmitted along the course of the anterior and posterior tibial vessels and up the femoral vessels to the groin. On obliteration of the fistula the pulse rate fell from 84 to 74, and the blood pressure changed from 120/84 to 130/94. Transverse cardiac measurements were normal. The left foot was cyanotic on dependency and pallid on elevation. The oscillometric readings at the left popliteal level were higher than on the right. The skin temperature of the toes was two degrees lower on the right than on the left.

On October 17, 1944, operation was performed. The upper third of the left fibula including the head was subperiosteally resected. A fistula communicating with a false sac, one inch in diameter, was completely excised after ligating the major proximal and distal vessels and numerous communicating vessels (Fig. 5). The patient's recovery was uneventful.

*Case 5.—A-V fistula, left posterior tibial vessels resulting from shell fragments July 6, 1944. Subperiosteal resection, upper third of left fibula. Quadruple ligation and excision of fistula October 18, 1944. Recovery.*

On July 6, 1944, this 23-year-old soldier received multiple wounds of both lower extremities with a compound fracture of the upper third of the right fibula produced by shell fragments. The right leg at the site of the fracture bled profusely, and was controlled by a tourniquet. The following day débridement was carried out. A large wound of the left popliteal space was treated by skin graft. A month after the injury the presence of a thrill and bruit was noted along the upper outer aspect of the left leg, and he was evacuated to the Zone of Interior, and admitted to Ashford General Hospital October 2, 1944.

He complained of a "buzzing" sensation in the left leg, sweating of the left foot, and swelling on dependency.

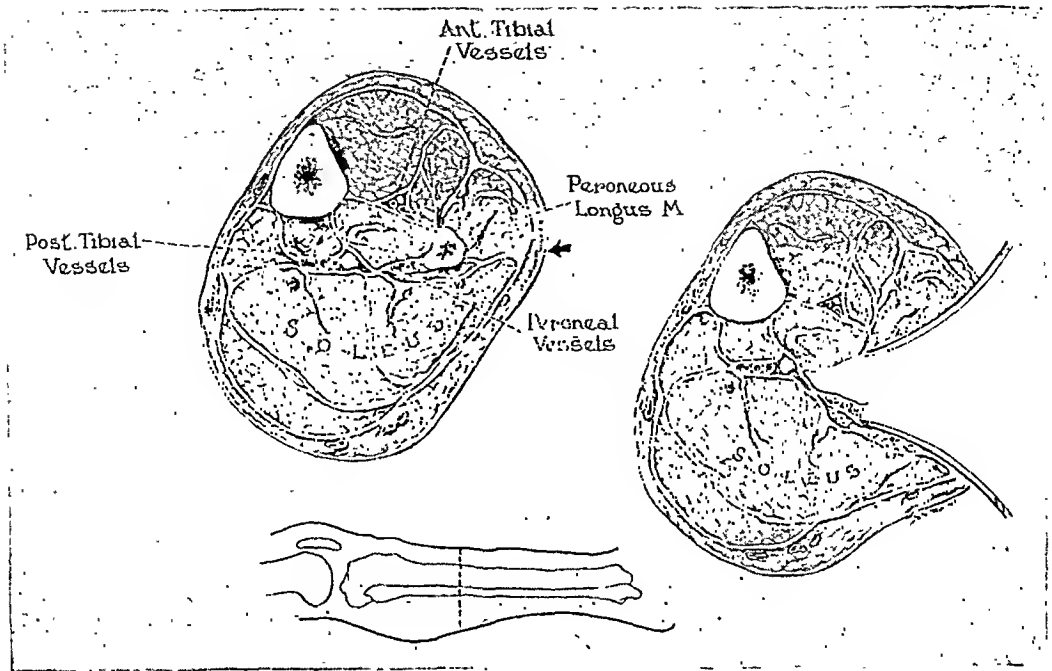


FIG. 4.—Cross-section of leg at level indicated in insert, showing exposure of vessels at this level after resection of fibula and retraction of muscles.

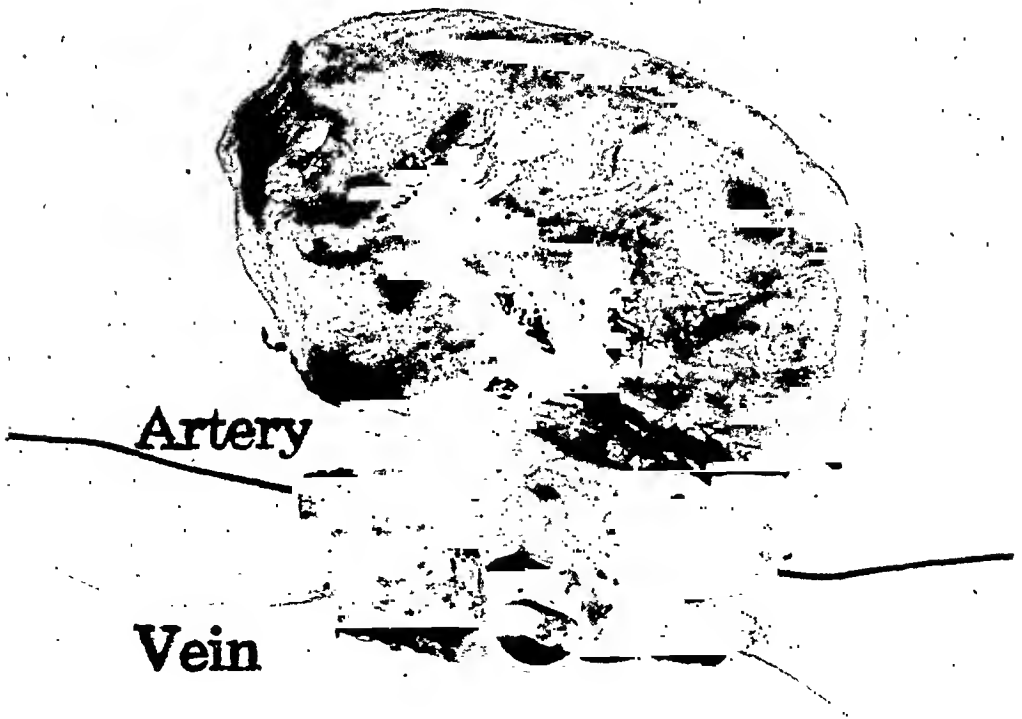


FIG. 5.—Case 4: Fistula with false sac. A window has been cut at the area of the fistula showing communication between artery and vein.

## ARTERIOVENOUS ANEURYSM

There were multiple wounds of both lower extremities and a large healed scar on the lateral upper aspect of the left leg and a well-healed area of grafted skin in the left popliteal space. There was a thrill along the upper lateral aspect of this leg with a rough continuous bruit heard loudest in the upper third of the leg and transmitted down the calf and upward to the groin. On obliteration of the fistula the pulse rate fell from 100 to 80, and the blood pressure changed from 120/90 to 140/100. Cardiac measurements were normal.

On October 18, 1944, the upper-third of the left fibula was resected subperiosteally, and after ligating numerous vessels of entrance and exit, a fistula between the upper tibial vessels was excised. Its position required ligation and division not only of the tibial vessels but of the origin of the anterior tibial and peroneal vessels as well. It was believed that successful ligation of these vessels could not have been carried out without resection of the fibula and subsequent easy access to the arteries and veins perforating the interosseous membrane. Recovery was uneventful.

*Case 6.—A-V fistula, left posterior tibial vessels resulting from shell fragments July 15, 1944. Complete paralysis peroneal nerve. Resection of upper third of fibula, excision of fistula, exploration of irreparable peroneal nerve injury, excision of scar, November 3, 1944. Mild secondary infection. Cure of A-V fistula. No improvement in nerve function.*

On July 1, 1944, this 22-year-old soldier was struck with shell fragments and suffered multiple wounds of the left lower extremity and hip. There was a severe wound overlying the upper half of the left fibula. None of the wounds bled excessively. The wounds were immediately débrided, shell fragments removed, and the wounds secondarily closed. Because of the peroneal nerve injury he was evacuated to the Zone of Interior and shortly thereafter evidence of an arteriovenous fistula of the left leg was noted. He was admitted to Ashford General Hospital October 18, 1944.

He complained of left drop foot, coldness, tingling, and numbness of the left leg and foot.

There were numerous healed sutured scars along the lateral and posterior aspects of the left lower extremity from the buttocks to the ankle. Just distal to the head of the left fibula there was a well defined thrill. A harsh continuous bruit, accentuated in systole, was best heard in this region and was transmitted upward to the groin and downward to the foot. Upon obliteration of the fistula by pressure the pulse rate fell from 80 to 60, and the blood pressure changed from 120/60 to 120/74. The cardiac measurements were normal. Oscillometric readings were increased at the left popliteal level and diminished in the left foot. The skin temperatures in the toes of both feet were below normal, and slightly lower in the left than on the right.

On November 3, 1944, the scar over the upper left fibula was excised, and the upper third of the fibula, including the head, was resected subperiosteally. A fistula between the posterior tibial vessels was found two centimeters distal to the origin of the peroneal artery. It was completely excised after ligating its major branches. A small false sac, lying on the lateral side of the fistula, was not removed. Following excision of the fistula exploration of the peroneal nerve was carried out. It was found to be divided at the point where it passed posterior to the head of the fibula. The distal portion was found in the substance of the peroneal muscles. Approximately four inches of this nerve had been shot away, and both ends were the seat of neuromas. After the removal of the neuromas the hiatus between the ends could not be breached, but the leg was flexed and a bridge of tantalum wire placed between the two ends in case further exploration was deemed advisable.

Following operation mild infection developed in the skin, probably the result of tension at the site of scar excision. The infection cleared rapidly without the necessity of secondary closure or skin graft. There has been some improvement in the nutrition of the leg following excision of the fistula. The extent of the nerve lesion probably precludes improvement in its function.



**Case 7.**—*A-V fistula, right anterior tibial vessels resulting from shell fragments, June 26, 1944. Resection of the upper third of the fibula, excision of the fistula November 25, 1944. Recovery.*

On June 22, 1944, this 25-year-old soldier received multiple shell wounds of both lower extremities, chest, eye, and nose. Although bleeding was profuse he was able to walk five miles to his own line. The wounds were débrided on June 25, 1944, and later were secondarily closed. About six weeks later a thrill in the upper right leg was discovered by a physiotherapist in the course of treatment. He was evacuated to the Zone of Interior, and admitted to Ashford General Hospital November 16, 1944.

He complained of pain in his right ankle, coldness, and excessive sweating of the right foot and a "buzzing" sensation along the upper anterior portion of the right leg.

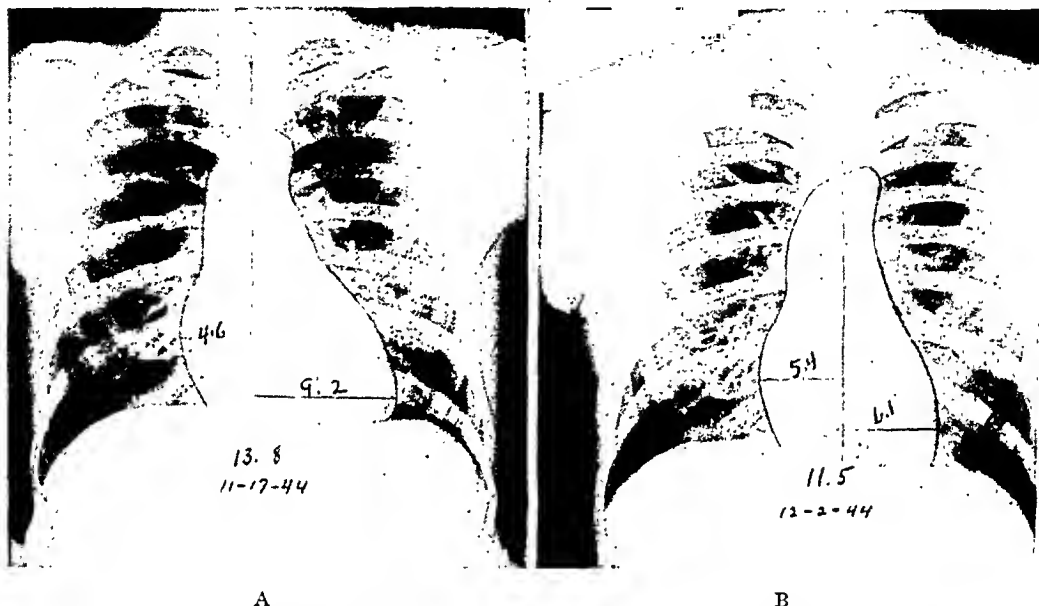


FIG. 6.—Case 7: A. Teleoroentgenogram of heart before operation. B. The heart shadow seven days after operation, showing reduction in cardiac diameter.

The right anterior thigh and leg were peppered with multiple wounds, well healed. There was a thrill over the anterolateral aspect of the upper portion of the right leg. It was also felt posteriorly in this region but not so marked as on the anterior surface. In this region a loud continuous bruit accentuated in systole was heard which was transmitted upward to the popliteal space and downward to the foot. On obliteration of the fistula the pulse rate fell from 72 to 52, and the blood pressure changed from 110/70 to 118/80.

On November 25, 1944, the upper third of the left fibula, including the head, was resected subperiosteally. The lower end of the popliteal artery was isolated and a suture, which was not tied, was passed around it. The fistula was found just distal to the origin of the anterior tibial artery, so near the popliteal artery that it was necessary to ligate that vessel in its removal. The anterior tibial artery and vein just distal to the fistula were ligated and divided and the fistula removed in its entirety. The transverse cardiac diameter was 13.8 cm. before operation. Two weeks after operation this had decreased to 11.5 cm. (Fig. 6). Recovery was uneventful.

**Case 8.**—*A-V fistula, right posterior tibial vessels, resulting from shell fragments, July 15, 1944. Resection upper third of fibula. Excision of fistula January 6, 1945. Recovery.*

On July 15, 1944, this 24-year-old soldier received multiple shell fragment wounds of the right leg, left foot, and both buttocks. Bleeding from the right leg was profuse,

but no tourniquet was applied. The injury was behind enemy lines, and he did not receive aid for ten hours. He was evacuated to England the following day, the wounds were débrided, and closed secondarily. Shortly thereafter the presence of an arteriovenous fistula was noted. The patient was evacuated to the Zone of Interior, and admitted to Ashford General Hospital on November 29, 1944.

He complained of "buzzing" sensation in the right upper leg with coldness and blueness of both feet, most marked on the right.

There were multiple small wounds over the anterior and posterior aspect of the right lower extremity. There was a long healed scar over the medial aspect of the right leg. There was a definite thrill over the anterolateral aspect in the right leg near the head of the fibula. A loud, harsh, continuous bruit could be heard over this region and was transmitted upward into the popliteal region and downward to the foot. Upon obliteration of the fistula the pulse rate fell from 72 to 64, and the blood pressure changed from 116/68 to 118/80.

On January 6, 1945, the upper third of the fibula, including the head, was resected subperiosteally and the posterior tibial vessels which were the seat of the fistula were exposed. The proximal artery and vein were identified and sutures passed around them which were not tied. The proximal vessels were greatly dilated. The veins distal to the fistula, which were dilated, were ligated and divided. The artery distal to the fistula, which was small, was ligated and divided. The proximal artery was then ligated and divided, and the fistula was removed from below upward after ligating numerous small vessels which entered it. The proximal vein was ligated as the last step in the procedure. The transverse diameter of the heart was 14.7 cm. before operation. Six weeks after operation this had decreased to 13 cm. Recovery was uneventful.

*Case 9.—A-V fistula, right posterior tibial vessels, resulting from shell fragments September 23, 1944. Resection of upper third of fibula. Excision of fistula January 12, 1945. Recovery.*

On September 23, 1944, due to mortar shell fragments, this 25-year-old soldier received multiple wounds of both lower extremities, chest, and right forearm. Bleeding was not profuse. Sixteen hours later the wounds were débrided, and at that time a compound fracture of the right tibia was found and the right leg was immobilized in plaster. Later, an arteriovenous fistula was found in the upper posterior surface of the right leg. He was evacuated to the Zone of Interior, and admitted to Ashford General Hospital December 19, 1944.

He complained of "buzzing" sensation in the upper part of the right leg, stiffness of the right knee, and coldness of the right leg.

There were numerous small, well-healed wounds over the leg, thigh, and body. On the upper posterior surface of the right leg there was a well-defined thrill and a continuous bruit transmitted upward to the popliteal vessels and downward to the foot. Upon obliteration of the fistula the pulse dropped from 96 to 80, and the blood pressure changed from 120/70 to 120/88.

On January 12, 1945, the upper third of the fibula, including the head, was removed. The fistula was located at the upper portion of the posterior tibial vessels. The proximal vein was dilated to twice its normal size. The artery, which was likewise dilated, was isolated and a suture passed around it, which was not tied. The tibial nerve was closely associated with the fistula and was dissected free from it. The distal veins were greatly dilated, and their ligation and division were accompanied with some difficulty because of hemorrhage resulting from the injury to one of them. This required mass ligation of the distal vessels. The proximal artery and vein were ligated and divided, and the aneurysmal mass was removed after ligating and dividing a number of communicating vessels. Prior to operation the transverse cardiac diameter was 14.4 cm. Two months after operation this had decreased to 12.2 cm. (Fig. 7). Recovery was uneventful.

**Case 10.**—*A-V fistula, right peroneal vessels secondary to machine gun wound September 4, 1944. Resection middle half of fibula. Quadruple ligation and excision of fistula, January 19, 1945. Recovery.*

This 32-year-old soldier was injured by machine gun fire on September 4, 1944, suffering a compound fracture of the right arm and wounds of both lower extremities. Shortly after the injuries the wounds were débrided and the right arm was placed in a plaster encasement. About a month after injury the patient discovered pulsation in the right calf and, because of this, he was evacuated to the Zone of Interior and eventually to Ashford General Hospital.

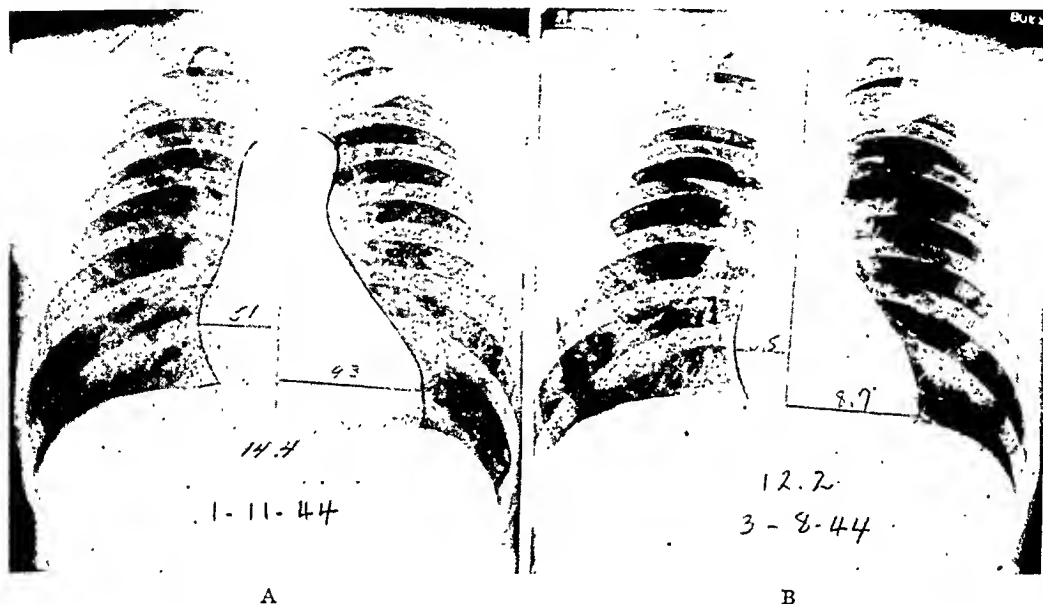


FIG. 7.—Case 9:— A. Teleorcentgenogram of heart before operation. B. Reduction in cardiac diameter two months after operation.

Physical examination showed incomplete union of the right humerus. The right leg, particularly the calf region, was swollen, and in the upper portion of this leg there was a well-defined thrill and continuous bruit, accentuated in systole. On obliteration of the bruit there was no drop in the pulse rate. The cardiac diameter was not increased.

On January 19, 1945, under spinal anesthesia, incision was made along the lateral border of the fibula and the middle half of that bone was excised. In separating the peroneus longus and soleus muscles the fistula was found in the peroneal vessels at the junction of the upper and middle thirds of the leg. It was completely excised after ligating its main branches and all communicating vessels. The excised fibula was not replaced. Patient's recovery was uneventful. He was transferred to the Orthopedic Section for continuation of treatment for the ununited fracture of the humerus.

**Case 11.**—*A-V fistula, with false sac, left peroneal vessels, resulting from shell fragments June 3, 1944. Resection middle third of fibula; excision of fistula with false sac January 26, 1945. Complete recovery.*

On June 3, 1944, this 21-year-old soldier was injured by mortar shell fragments which produced wounds of both legs and the right forearm. Bleeding from the left leg required a tourniquet. He was rapidly taken to an Evacuation Hospital where the wounds were débrided, and where a compound comminuted fracture of the left tibia and fibula was discovered. This was treated by plaster immobilization. In spite of some infection the wounds healed and immobilization was discontinued on September 6, 1944, at which time the patient became conscious of a pulsating "buzzing" mass in the left calf. This was later brought to the attention of his medical officer, and he was later brought to Ashford General Hospital on January 11, 1945.

# ARTERIOVENOUS ANEURYSM

FIG. 8

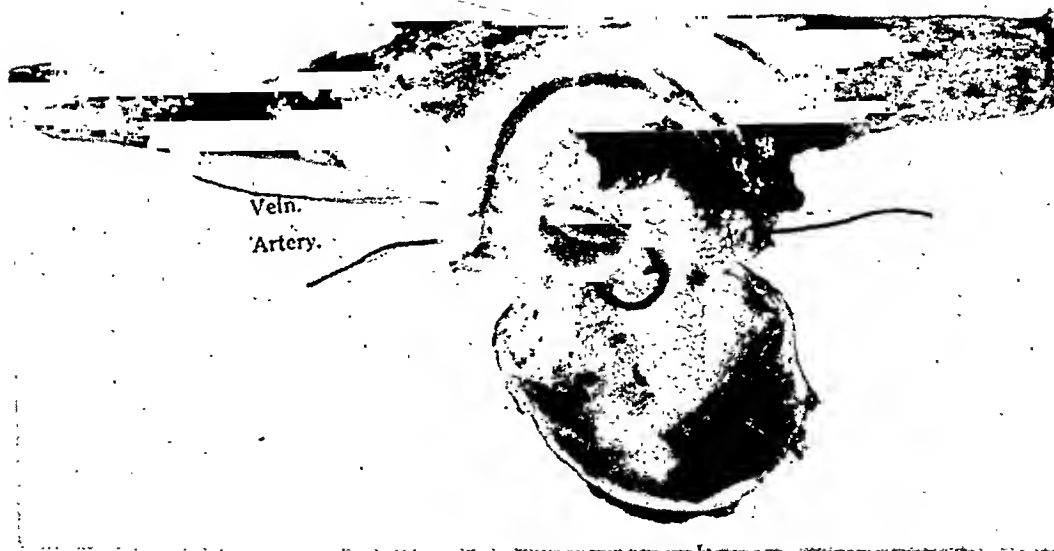
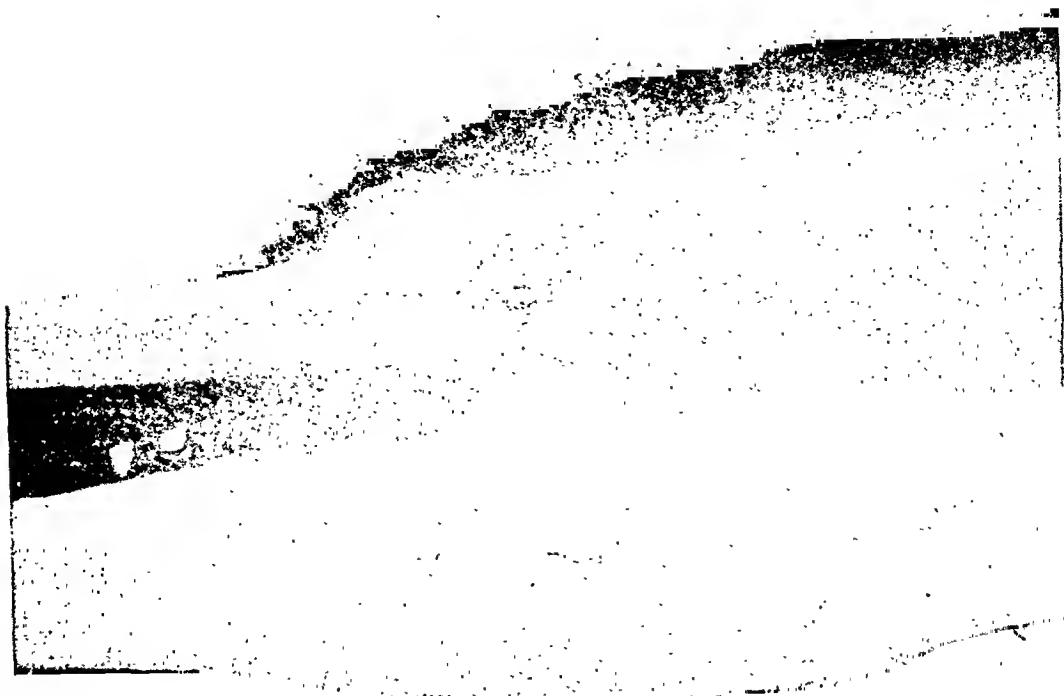


FIG. 9

FIG. 8.—Case 11: Roentgenogram showing pressure necrosis of fibula by aneurysm at site of fracture.

FIG. 9.—Case 11: The specimen, showing portion of fibula removed with false aneurysmal sac in eroded bone. The sac has been opened to show communication with artery and vein.

He complained of the pulsation in the left calf, aching of the left leg and ankle, with stiffness, swelling, and cyanosis of the foot. Radiography of the leg (Fig. 8) revealed a well-healed fracture of the left tibia and a healed fracture of the fibula, with considerable necrosis of the bone at the point of fracture, believed to be due to pressure necrosis of the aneurysm.

There were two wounds, six inches long, over the middle portion of the tibia and fibula which were well healed. In the midportion of the leg, just posterior to the fibula, there was a pulsating mass, about two inches in diameter, over which a continuous thrill could be felt. In this region there was a continuous bruit transmitted upward to the popliteal space and downward into the foot. Upon obliteration of the fistula the pulse rate dropped from 100 to 84; and the blood pressure changed from 130/70 to 120/82. The pulsation, which in this region was just posterior to the fibula at the point of fracture, was believed to be limited by the bone itself which formed a barrier to the aneurysm. A diagnosis of arteriovenous fistula of the posterior tibial vessels, with a communicating false sac eroding the posterior surface of the fibula and limited by that bone, was made. In view of these findings resection of the fibula as a preliminary to excision of the fistula and sac seemed imperative.

On January 26, 1945, the sac was partially emptied by elevation and application of a pressure bandage, and a pneumatic tourniquet about the thigh was inflated. The scar over the fibula was excised and approximately six inches of the middle third of the fibula was resected subperiosteally. Considerable difficulty was encountered because of the bizarre configuration of the fibula at this level resulting both from the healed fracture and from the erosive changes produced by the pressure of the false sac (Fig. 9). Following resection of the fibula the peroneal vessels were isolated, both proximal and distal to the sac. Although removal of the tourniquet had been contemplated at this point, some of the proximal veins, poorly demarcated in their collapsed condition, were torn. Because of the resultant venous bleeding, the source of which was difficult to determine, the remainder of the procedure was carried out with more than the usual difficulty because of lack of definition of the partially collapsed vessels. Following ligation of the main communicating vessels of the fistula and its excision, the tourniquet was removed and many small communicating vessels ligated. The removal of the fistula necessitated division of the neck of the false sac, which was removed separately. The transverse cardiac measurement before operation was 13.2 cm. Six weeks later this had decreased to 12.5 cm. Recovery was uneventful.

*Case 12.—A-V fistula, right posterior tibial vessels, resulting from shell fragment wound November 18, 1944. Resection upper third of fibula. Quadruple ligation and excision of fistula. Recovery.*

This 21-year-old soldier was wounded by shell fragment November 18, 1944. There was a through-and-through wound of the right upper leg just below the level of the tibial tubercle. Profuse bleeding was controlled by pressure. After a month of hospitalization swelling was noted along the medial aspect of the leg. A diagnosis of arteriovenous fistula was made, and he was evacuated to the Zone of Interior, and admitted to Ashford General Hospital February 7, 1945.

On examination, the wounds previously noted were well-healed. There was a thrill, both anteriorly and posteriorly in the upper portion of the right leg, and a continuous bruit accentuated in systole and transmitted upward along the course of the femoral vessels and downward to the foot. On obliteration of the fistula there was a drop in pulse rate from 80 to 64; and the blood pressure changed from 110/64 to 110/76. There was mild cyanosis on dependency of the right foot. The pulsations of the dorsalis pedis and posterior tibial vessels were diminished on the right side. Skin temperatures of the right toes were four degrees lower than on the left. The cardiac diameter was not increased.

On February 22, 1945, operation was performed and the upper half of the right fibula, including the head, was resected subperiosteally. The peroneal nerve was secured

# ARTERIOVENOUS ANEURYSM

and dissected free from surrounding tissues as a preliminary step in this operation. When the peroneal and soleus muscles were separated the posterior tibial vessels were brought into direct view. The fistula was found in the posterior tibial artery just proximal to the origin of the anterior tibial artery. It was completely excised by dividing the anterior tibial vessels as well as the posterior tibial vessels, both proximal and distal to the fistula. The fibula was not replaced. The deep fascia and skin were closed with interrupted sutures of silk. His recovery has been complete, and there is good stability of the knee joint.

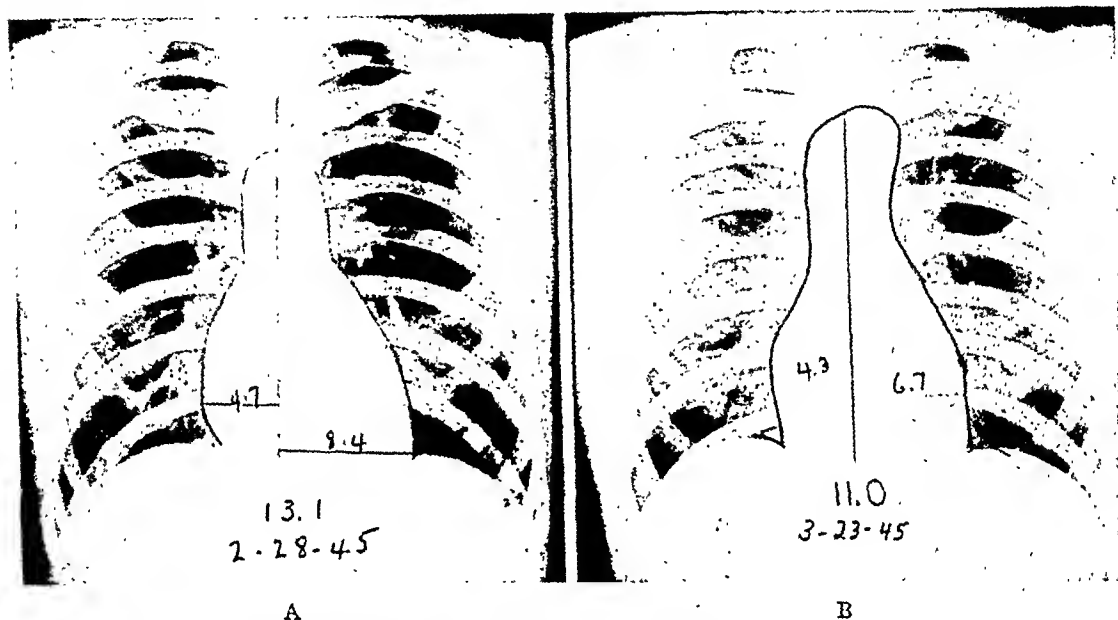


FIG. 10.—Case 14: A. Teleoroentgenogram of the heart before operation. B. The heart 13 days after operation, showing reduction in cardiac size.

**Case 13.**—*A-V aneurysm, with false sac, left peroneal vessels; A-V fistula anterior tibial vessels, both resulting from shell fragment wounds November 14, 1944. Resection upper third of fibula; proximal and distal ligation of peroneal vessels and intrasacral suture (Matas). Excision of A-V fistula anterior tibial vessels, March 1, 1945. Recovery.*

This 27-year-old soldier was wounded in action on November 14, 1944. He suffered one through-and-through wound in the upper portion of the left leg. A tourniquet was applied to control the bleeding. The wounds were débrided three days later. Two months after the injury the presence of an arteriovenous fistula was discovered in the left leg just below the knee, and for this he was evacuated to the Zone of Interior, and admitted to Ashford General Hospital February 15, 1945.

On examination, there were two well-healed wounds on the lateral and medial side of his leg about four inches below the knee. In the upper part of the calf there was an expansile pulsation with a continuous thrill. The thrill was transmitted all over the leg and up the thigh along the course of the femoral vessels. It was particularly prominent over the pulsating mass and on the anterior surface of the leg just below the knee. A continuous bruit accentuated in systole was heard over the leg and transmitted upward to the groin. Obliteration of the fistula by pressure caused a drop in pulse rate from 72 to 60; and a change in blood pressure from 110/60 to 110/80. There was marked increase in oscillometry in the region of the fistula.

On March 1, 1945, the upper half of the fibula, including the head, was resected subperiosteally. During the resection of the fibula considerable bleeding was encountered because the false sac was entered in the stripping of the periosteum from the bone. A tourniquet previously placed about the thigh was inflated. The fistula was found to be in the peroneal vessels which entered a large false sac. The proximal and distal

vessels were ligated and divided and the sac opened and five openings were closed by intrasacular suture, after the method of Matas. The tourniquet was removed and all bleeding points were ligated. It was then found that another fistula existed between the anterior tibial vessels about two inches distal to the origin of this artery. This fistula was excised after ligating the proximal and distal vessels which entered it. The resection of the fibula gave excellent exposure to both fistulae, and it was felt that this exposure could not have been obtained without a preliminary resection of the bone. His recovery was uneventful.

**Case 14.**—*A-V fistula, with false sac, left peroneal vessels, due to bullet wound sustained November 24, 1944. Resection of upper third of fibula, excision of fistula and sac, scar excision, and secondary closure with skin graft, March 8, 1945. Superficial infection. Recovery.*

This 21-year-old soldier was wounded by a bullet on November 24, 1944, the missile entering the medial aspect of the leg about three inches below the knee. A tourniquet was necessary to control hemorrhage. Shortly thereafter a compound fracture of the middle third of the fibula was débrided and the leg immobilized in plaster. Upon removal of the plaster the presence of an arteriovenous fistula was discovered, and he was admitted to Ashford General Hospital February 22, 1945.

Upon examination, there was a well-defined thrill and bruit over the lower popliteal space which was transmitted up the course of the femoral vessels and down into the leg. There were two longitudinal scars on the posterior aspect of the left leg. Upon obliteration of the fistula the pulse rate dropped from 72 to 60; and the blood pressure changed from 130/70 to 130/90.

Operation was performed March 8, 1945, and a ten-inch scar on the lateral surface of the leg was excised, and incision was carried three inches above the knee. After isolating the peroneal nerve, the upper third of the fibula, including the head, was resected subperiosteally. The fibula had previously been fractured at the junction of the proximal and middle thirds, and approximately one inch of the distal fragment was likewise resected. After the posterior periosteum was opened the fistula was found to be between the peroneal artery and vein, about four inches below the knee. The proximal and distal vessels were identified and ligated, and the fistula, together with the false sac, was completely excised. Several communicating vessels of considerable size were divided at the point where they entered the fistula. It was necessary to make a relaxing incision on the medial aspect of the leg in order to close the wound, and this was covered with a split-thickness skin graft. Some superficial infection developed in the wound, probably due to tightness of the closure. This cleared up rapidly. Prior to operation the transverse cardiac diameter was 13.1 cm., which decreased to 11 cm. ten days after operation (Fig. 10). The grafted area of skin healed normally, and there is no evidence of recurrence of the fistula.

**Case 15.**—*A-V fistula with false sac, left anterior tibial vessels, due to land mine fragments, November 28, 1944. Resection upper third of fibula, quadruple ligation and division anterior tibial vessels; intrasacular suture of false sac (Matas) March 15, 1945. Recovery.*

This 26-year-old soldier was wounded by fragments of a land mine on November 28, 1944. He suffered multiple wounds of both lower extremities, and a through-and-through wound of the upper portion of the left leg. Bleeding was not profuse from any wound. Shortly thereafter the wounds were débrided. The patient was conscious of a throbbing in the upper portion of the left leg soon after the injury, but it was not until after evacuation to the Zone of Interior that presence of a fistula was noted. He was admitted to Ashford General Hospital on March 1, 1945.

On examination, there were numerous small healed wounds in both lower extremities. There was a larger wound of entry on the upper portion of the calf three inches below the knee. There was a large pulsating mass on the anterior portion of the leg just below the knee and, in addition, a continuous thrill and bruit, accentuated in systole, heard all

over the upper portion of the leg and transmitted to the foot and to the groin. On obliteration of the fistula the pulse rate dropped from 76 to 64. There was no change in the blood pressure, which was 110/70. Transverse cardiac diameter was normal.

Operation was performed March 15, 1945. The upper half of the fibula, including the head, was resected subperiosteally. In removing the fibula it was found that this bone formed a portion of the false sac, which was opened. Bleeding was controlled by the inflation of a pneumatic tourniquet which had been applied previously. The sac was opened and dissection revealed that the sac communicated with the anterior tibial artery and vein. These vessels were isolated both proximal and distal to the sac, and ligated and divided. The openings in the sac were closed with interrupted sutures. A portion of the sac was excised, and the remainder was infolded with a series of sutures. On removal of the tourniquet there was no bleeding, and the wound was closed in the usual manner in layers. Recovery was uneventful.

#### SUMMARY AND CONCLUSIONS

Careful exposure of the tibial and peroneal vessels in the upper part of their course is necessary in the operative treatment of arteriovenous fistulae in this region. This is facilitated by subperiosteal resection of the fibula, including the head of the bone if necessary. The resected portion of bone is not replaced. There has been no instability of the knee joint following this operation. Fifteen consecutive cases in which this procedure was carried out are presented in abstract.

We are indebted to Kathleen Mackay and T/5 V. Destro for the illustrative drawings, and to Captain Floyd B. Hall and T/5 Joseph Jackson for photographs.

#### REFERENCE

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# THE SURGICAL TREATMENT OF THE MORE COMMON TYPES OF DIAPHRAGMATIC HERNIA: ESOPHAGEAL HIATUS, TRAUMATIC, PLEUROPERITONEAL HIATUS, CONGENITAL ABSENCE AND FORAMEN OF MORGAGNI\*

REPORT OF 404 CASES

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ALTHOUGH THE OCCURRENCE of herniation of abdominal viscera through the diaphragm is relatively uncommon when compared with herniation through the abdominal wall, there are more different kinds of hernia occurring through the diaphragm than there are occurring through the other walls which encase the abdominal contents. The reason for the different types of diaphragmatic hernia is the unusual embryologic formation of the diaphragm, which makes it more susceptible to weak areas through which these herniae may occur.

The formation of the diaphragm from embryonic structures is a highly complex process, because the muscular elements of the diaphragm are derived from several sources. The anterior, lateral and central parts, which comprise the greater portion of the diaphragm in the adult person, are formed from the transverse septum and fused ventral mesentery. The remaining, posterolateral portion is formed by the fusion of the dorsal mesentery and the mesoderm derived from the receding wolffian body with the pleuroperitoneal membrane derived from the pulmonary ridge. It is difficult to determine the exact amount of the muscle tissue that is derived from each of these structures, since considerable variation probably occurs during the process, but it is likely that the dorsal mesentery forms the posterior and central portions, which contain the esophageal opening. The mesodermal cells from the receding wolffian body form the right and left crura. The pleuroperitoneal membrane grows ventrally, closes the remaining opening (hiatus pleuroperitonealis) between the peritoneal celom and the pleural celom by fusion with the transverse septum and forms the lateral portion of the diaphragm.

Failure of fusion or failure of proper deposition of the mesoderm at any one of these adjacent points of union may result in congenital continuity of the pleural and peritoneal cavities or a congenitally weak portion in the diaphragm at any of these points. Consequently, from an embryologic standpoint, weak portions might be expected to appear at the points of fusion of these different structures. These portions are situated dorsolaterally at the fissura pleuroperitonealis (foramen of Bochdalek) and also through the outer crus and through the esophageal opening. Herniation through the

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\* This paper was to have been presented before the Annual Meeting of the American Surgical Association, May, 1945.

dome is common but cannot be explained on the foregoing basis, because the dome, embryologically, is not a fusion region. Such a hernia may be the result of excessive degeneration of the muscle in the formation of the central tendon or of some pathologic condition. Unilateral absence of the diaphragm probably is the result of the failure of development of the pleuro-peritoneal membrane, which usually is found as a narrow ridge of tissue along the posterior wall of the thorax.

#### CLASSIFICATION OF DIAPHRAGMATIC HERNIA

There are numerous classifications of diaphragmatic hernia which are based on the embryologic and etiologic aspects, pathologic anatomy, the site of the opening in the diaphragm, the presence or absence of a sac, the contents of the hernia, and other factors. It is difficult, or impossible, to make most of these classifications clinically; accordingly, many of them are of little practical value.

All types of true hernia have a sac as one of the component parts; so that many conditions, commonly included under this term but in which there are no hernial sacs, would more properly be termed "evisceration" or "false hernia." The presence or absence of an hernial sac cannot be determined by clinical examination. It can be found only at operation.

From a clinical and surgical standpoint, the history of a preceding injury is helpful in establishment of the diagnosis and in determination of the type, urgency and prognosis of the operative treatment. Because of the practical clinical and surgical significance of trauma as an etiologic factor, I have suggested that diaphragmatic hernia be classified into two main groups: Nontraumatic and traumatic. I have subdivided these two groups according to the various types.

*Nontraumatic Hernia.*—A nontraumatic diaphragmatic hernia may be congenital or acquired. If it is congenital, the hernia is attributable to embryologic deficiency and usually does not have an hernial sac. The most common sites of a congenital hernia, in the probable order of frequency of occurrence, are: (1) Through the hiatus pleuroperitonealis (foramen of Bochdalek); (2) through the esophageal hiatus; (3) through an anterior substernal opening (foramen of Morgagni or Larrey's space); and (4) through the gap left by partial absence of the diaphragm, a gap which is usually situated in the posterior portion of the muscle.

If the hernia is acquired after birth, the sites of occurrence are: (1) Through the esophageal hiatus, a type in which there is an hernial sac; (2) through the region of fusion of the anlage of the diaphragm; and (3) at sites named under the congenital type in the foregoing paragraph.

*Traumatic Hernia.*—Traumatic diaphragmatic hernia may be caused by direct or indirect injury or by inflammatory necrosis of the diaphragm. In case of indirect injury of the diaphragm, the hernia may occur at any point, including points of embryologic fusion, but the most common sites are the dome and the posterior half of the left part of the diaphragm. On the other

hand, the hernia may occur in the right part of the diaphragm. It usually is the result of a severe, crushing injury. When the hernia occurs through the esophageal opening there is a sac but when it occurs through the leaf of the diaphragm there usually is no sac. In case of direct injury of the diaphragm, the hernia may occur at any point and is usually the result of penetrating wounds, such as those inflicted by a gun or knife.

Rupture of the diaphragm may be the result of inflammatory necrosis, which, in turn, has been caused by subdiaphragmatic abscess. Again, rupture may follow necrosis caused by drainage tubes which have been introduced into empyematic cavities. In these cases the opening usually is situated in the posterior part of the diaphragm and there is no hernial sac.

#### CLINICAL AND SURGICAL CONSIDERATIONS

In my experience, the most common types of diaphragmatic herniae, in order of frequency, which require surgical treatment are esophageal hiatus hernia; herniae due to trauma, indirect or direct, or to inflammatory necrosis; absence of a portion of the diaphragm; hiatus pleuroperitonealis herniae and herniae through the foramen of Morgagni (Fig. 1).

The number of diaphragmatic herniae of each of these types in the 404 cases in which I have operated is shown in Table I. Each of these various types of diaphragmatic hernia presents different clinical manifestations as well as different methods of surgical treatment. It will not be possible to go into detail but I shall present some of the more important clinical and surgical considerations of these different types of diaphragmatic hernia.

The clinical recognition of diaphragmatic hernia on the basis of the subjective symptoms alone is often very difficult. The symptoms are complex because of the various structures involved in the hernia and depend on the amount of mechanical interference with the function of the herniated abdominal viscera, on the degree of impairment of the normal function of the diaphragm and on the amount of increased pressure within the thorax which causes impairment of respiration and circulation.

The clinical syndrome of diaphragmatic hernia may be divided into two main groups. The first group occurs in cases in which the stomach is the only abdominal organ involved in the hernia. The symptoms are those of intermittent and usually progressive incarceration and obstruction of the stomach. The most common type of diaphragmatic hernia in which the stomach is the only abdominal viscus involved is through the esophageal hiatus. However, this type of hernia may contain various portions of the omentum, depending on the amount of stomach involved in the hernia. Inasmuch as these herniae are progressive, the entire stomach may become involved in the hernia and in these herniae the colon may also become incorporated in the hernial sac because of its attachment to the greater curvature of the stomach. More rarely the spleen may become involved because of its attachment to the cardia of the stomach. In these cases, in

# DIAPHRAGMATIC HERNIA

TABLE I

DATA IN 404 CASES OF DIAPHRAGMATIC HERNIA IN WHICH OPERATION WAS PERFORMED

Site of Opening	Cases	Cause	Contents of Hernia	Cases
Esophageal hiatus	287	Congenital (history of trauma, 17)	Stomach (omentum)	266
			Stomach, omentum and spleen	6
			Stomach and colon	15
Short esophagus type	33	Congenital (11)	Stomach only	33
Hiatus pleuroperitonealis	0	Congenital	Right colon and small bowel	4
			Colon, small bowel, stomach and spleen	4
			Colon, small bowel and appendix	1
Absence of posterior fourth of diaphragm	12	Congenital	Stomach, colon, small bowel and spleen	5
			Small bowel and colon	2
			Small bowel, colon, spleen, appendix (3) and stomach (1)	5
Foramen of Morgagni (subcostosternal)	8	Congenital (right diaphragm 6; bilateral, 1)	Colon and omentum	7
			Stomach and colon	1
Traumatic: Left diaphragm	54	Trauma (indirect injury, 36; direct injury, 8)	Stomach only	7
			Stomach and colon	12
		Inflammatory necrosis (6)	Stomach, colon, small bowel (30), spleen (20) and liver (12)	35
Right diaphragm	1	Trauma (direct)	Stomach, colon, small bowel, liver (gallbladder) and head of pancreas	1
Total	404			404

TABLE II

SURGICAL PROCEDURES AND OPERATIVE RESULTS IN 404 CASES

Radical repair of defect in diaphragm:	
Approach: Abdominal, 369; thoracic, 2.....	371
Preliminary interruption of phrenic nerve.....	268
Preliminary extrapleural thoracoplasty.....	3
Operations in conjunction with repair of hernia:	
Gastric resection for gastric ulcer, 1; for carcinoma, 2.....	3
Closure of perforated gastric erosion, 2 (Total erosions, 37).....	2
Gastro-enterostomy for gastric ulcer, 1; for duodenal ulcer, 2.....	3
Splenectomy for tuberculosis, 2; for injury, 8.....	10
Appendicostomy for obstruction.....	1
Appendectomy for appendicitis.....	2
Interruption of left phrenic nerve (hiatus hernia):	
Palliative, 7; therapeutic, 26.....	33
Total patients operated upon.....	404
Recurrence of hernia of all types after operation:	
Traumatic hernia, 0; congenital defect, 1; esophageal hiatus, 9	
Recurrence of esophageal hiatus herniae, 9	
Roentgenologic diagnosis, without recurrence of symptoms, 5	
Roentgenologic diagnosis, with recurrence of symptoms, 4; repair of recurrent herniae, 4	
Operative deaths, 16 or 4.0% (basis of 404 patients operated upon)	

which the colon is involved, there may be additional symptoms of partial or complete intestinal obstruction.

The second group consists of those cases in which multiple abdominal viscera are involved in the hernia. These herniae are usually of traumatic origin and are caused by laceration of a normal diaphragm. However, they also may be of congenital origin and may result from congenital structural deficiency of the diaphragm. The symptoms in these cases are more varied and severe than those in the first group because of the multiple structures involved and are often more acute in onset. The initial symptoms may be those of acute intestinal or gastric obstruction or severe hemorrhage.

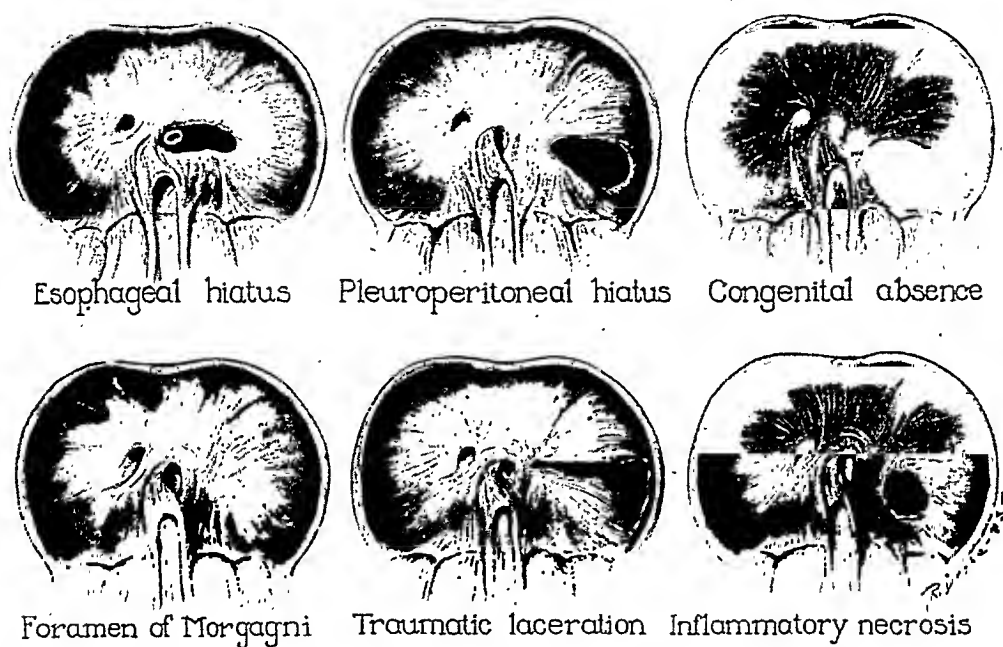


FIG. 1.—Situations of congenital structural defects and traumatic lacerations of the diaphragm which cause the more common types of diaphragmatic hernia.

From the standpoint of treatment, diaphragmatic hernia is primarily a mechanical condition and the only treatment which will relieve the condition is operative repair or reconstruction of the abnormal opening in the diaphragm after replacement of the herniated viscera into the abdomen. The indications for surgical intervention and methods and technic of surgical procedures depend on the type, situation and size of the defect in the structure of the diaphragmatic muscle, the kind and amount of abdominal viscera involved in the hernia and whether or not the viscera are enclosed in the hernial sac.

In the treatment of all herniae that have occurred through the left portion of the diaphragm, I prefer the abdominal approach by means of an oblique left rectus incision, starting at the ensiform cartilage and extending to the outer border of the rectus muscle. I believe there is less risk of the occurrence of thoracic complications when this approach is used. It is of particular advantage in cases of esophageal hernia, for the herniated stomach is usually

confined in a sac in the posterior part of the mediastinum and does not enter the true pleural cavity.

In the repair of herniae through the right portion of the diaphragm, I prefer the thoracic approach because the large, right lobe of the liver makes the abnormal opening in the diaphragm inaccessible from the abdominal approach.

The technical difficulties of adequate exposure of the hernial openings through the left portion of the diaphragm and the esophageal hiatus are often considerable because of fixation of the left lobe of the liver to the leaf of the diaphragm. The exposure of these hernial openings is greatly facilitated by cutting the suspensory ligament and retracting the left lobe of the liver to the right. This can be accomplished, when the left lobe is small, by folding it on itself, and when it is large, by retracting it forward into the wound. The spleen is often very adherent to the posterior part of the diaphragm and hernial openings, but usually can be separated from these structures by blunt dissection. In some instances the spleen has been so traumatized by the injury, and so bound into its abnormal position by adhesions, that it cannot be separated from the hernial opening without seriously injuring it. This not uncommonly occurs in the traumatic types of hernia, and occasionally in esophageal hiatus hernia. In these cases splenectomy is necessary.

Paralysis of the diaphragm, produced by temporary or permanent interruption of the phrenic nerve, is of value as a procedure preliminary to radical operative repair of esophageal hiatus herniae. It is a necessary procedure in the surgical treatment of partial thoracic stomach resulting from a congenitally short esophagus. In some cases in which radical operative repair is contraindicated, it may be used as a palliative measure.

#### ESOPHAGEAL HIATUS HERNIA

Herniation of the abdominal viscera through the esophageal hiatus is the most common type of diaphragmatic hernia occurring in adult life. These herniae are of considerable general interest because of the relative frequency of their occurrence, their indefinite causation, the variation of the relationship between the defective esophageal hiatus and the structures involved in the hernia, the progressive character of their development, the varied and complex symptoms produced by them and because of their treatment, which may be conservative if the herniae are small and symptoms mild but which may embrace surgical treatment if the herniae are large.

The symptoms of esophageal hiatus hernia may begin at birth or at any time during later life. Because of the progressive character of this type of hernia, the symptoms vary as the hernia becomes larger, depending on the degree and type of herniation present. Therefore, several different clinical diagnoses can be made in the same case, depending on the time at which the patient is examined, because of the changing symptoms. Accordingly, the condition may be termed the "masquerader" of the upper part of the abdomen. This, I believe, is the most important clinical consideration of

esophageal hiatus diaphragmatic herniae. In a study of 320 cases of this type of hernia in which I have performed operations, it was found that an average of three previous erroneous clinical diagnoses had been made in these cases before the correct diagnosis was established. The most common



FIG. 2a.—Patient, age 49. Esophageal hiatus hernia with herniation of the cardiac end of the stomach through the esophageal hiatus and some displacement of the lower part of the esophagus (previously diagnosed gallbladder disease).

b. Same patient. Enlarged esophageal hiatus repaired to the left of the esophagus with interrupted silk sutures and continuous sutures of fascia lata by lapping the anterior over the posterior margin of the opening.

c. Same patient three weeks after repair of the hernia. The entire stomach is below the diaphragm, which is elevated because of temporary interruption of the phrenic nerve. The esophagus is in normal position.



FIG. 3a.—Patient, age 17. Esophageal hiatus hernia with herniation of the pyloric two-thirds of the stomach into the right thoracic cavity. Stomach is enormously dilated due to incarceration and obstruction (previously diagnosed ulcer with obstruction).

b. Same patient. The enlarged hiatus, defective posteriorly, is repaired with interrupted silk sutures and continuous sutures of fascia lata by overlapping laterally in front of the aorta.

c. Same patient on dismissal, showing the entire stomach, in normal position below the diaphragm, which is elevated as result of temporary interruption of the phrenic nerve. The esophagus is in normal position.



erroneous diagnoses, in order of frequency, were found to be cholecystitis, cholelithiasis, gastric ulcer, duodenal ulcer, hyperacidity, secondary anemia, cardiac disease, carcinoma of the cardia, stricture of the esophagus, appendicitis and intestinal obstruction. In 32 of these cases the patients had been operated upon previously for other conditions, without complete relief of symptoms. They were completely relieved after repair of the hernia (Fig. 2).

The chief symptoms of esophageal hiatus hernia are pain, distress, gaseous eructation, vomiting, dyspnea, hemorrhage, weakness, anemia and palpitation of the heart. At the onset the symptoms are usually mild; they consist of epigastric distress that is projected through to the back and which comes on in the course of, or shortly after, a heavy meal. However, such attacks may be brought on by taking anything into an empty stomach, such as a cupful of coffee. The attacks are usually similar to one another in character but vary a great deal in intensity, depending on the amount of stomach that becomes incorporated in the hernia and the degree of interference with the diaphragm as well as the size of the hernial orifice and the occurrence of associated complications such as traumatic ulcer and incarceration of the stomach (Fig. 3).

In cases in which surgical treatment of the hernia is considered, one of the most important groups is that in which the symptoms simulate angina pectoris, for there are often no definite findings on which the diagnosis of coronary disease can be established. It is to be remembered that although a patient has a definite esophageal hiatus hernia that could adequately explain the symptoms, the patient can also have coronary sclerosis without proved signs and, if this condition is present, it constitutes a marked hazard to surgical intervention for the hernia.

From the standpoint of management hiatus hernia may be divided into three groups: In the first group the hernia is small, is recognized roentgenologically, often during the course of a general examination, and causes few or no clinical symptoms. No treatment is indicated in this group of cases. The second group includes those cases in which the symptoms are moderate and the herniae are of moderate size; in many of the cases in this group, conservative treatment, such as regulation of diet and reduction of weight, is sufficient to relieve the symptoms. The third group includes those cases in which there is no response to conservative measures; in these cases the herniae usually are large, and in many cases, in my experience, there are complications, such as incarceration of the stomach or gastric erosion. In this group of cases the only treatment that assures relief of symptoms is operative repair of the hernia.

In all cases in which a third or more of the stomach is involved in the hernia, surgical intervention should be considered, because the condition is progressive and usually the progressive enlargement becomes more rapid after the hernia has attained this size. Operation should be performed before severe incarceration, with consequent obstruction and traumatic lesions of the stomach, has occurred. The operative risk is increased by gastric reten-

tion and the technical difficulties are enhanced by fixation of the stomach to the diaphragm and to the hernial sac within the thorax. In all cases in which the colon is involved in the hernia, early operation is necessary because of the danger of occurrence of intestinal obstruction.

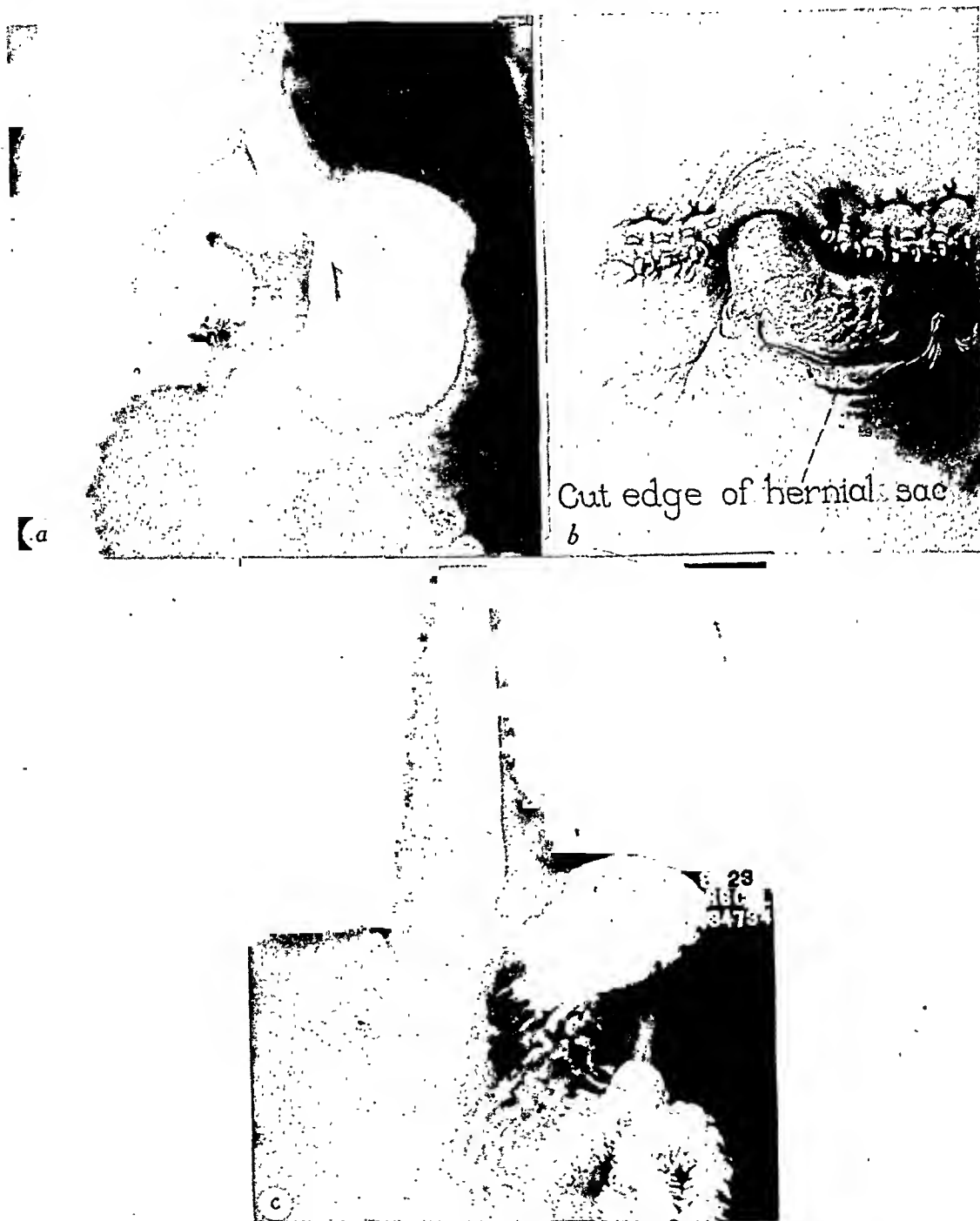


FIG. 4a.—Patient, age 55. Esophageal hiatus hernia with herniation of the entire stomach, which is inverted, and of a portion of the duodenum, with marked elevation of the esophagus and also herniation of the transverse colon through the esophageal hiatus.

b. Same patient. Repair of the markedly enlarged esophageal hiatus by overlapping the anterior margin over the posterior margin on both sides of the esophagus and at a higher level on the esophagus. Interrupted silk sutures and continuous sutures of fascia lata were used in the repair.

c. Same patient three weeks after repair of the hernia, showing the entire stomach in normal position below the diaphragm, which is slightly elevated as a result of interruption of the phrenic nerve. The esophagus is in normal position and extends to the diaphragm.

While all herniae through the esophageal hiatus are considered under the general term "esophageal hiatus hernia," there are three different types which are important from the standpoint of surgical technic. The first type consists of those cases in which the esophagus maintains its attachment to the diaphragm and the cardiac end of the stomach has herniated through the abnormal opening along the side of the esophagus. This is commonly called a para-esophageal hiatus hernia. It is, however, relatively infrequent and does not constitute more than 20 to 25 per cent of cases in which the patient comes to surgical treatment. The second type consists of those cases in which the esophagus is markedly retracted or shortened into the mediastinum but in which it is long enough to reach the diaphragm by traction. This type constitutes 75 to 80 per cent of cases in which treatment is surgical. The herniae are usually larger than those of the first type and the results are not as favorable from a surgical standpoint, for recurrences are more prone to develop because of the difficulty of reestablishing fixation of the lower part of the esophagus to the diaphragm. The third type is that of the true short esophagus with partial thoracic stomach, which may also include cases of cicatricial contraction with fixation of the esophagus. These cases present an entirely different surgical problem from the true esophageal hiatus hernia.

#### SURGICAL TREATMENT

In most cases of esophageal hiatus hernia, I prefer to perform temporary interruption of the phrenic nerve by crushing the nerve preliminary to abdominal repair of the hernia because permanent paralysis of the diaphragm is rarely necessary in this type of hernia. Following temporary interruption of the phrenic nerve the function of the diaphragm is usually reestablished in from three to six months. In cases in which reestablishment of function of the diaphragm is not desired because of the danger of recurrence of the hernia, paralysis can be made permanent by cutting or evulsing the phrenic nerve. As a procedure preliminary to radical surgical treatment, interruption of the phrenic nerve is often of value in treatment of incarcerated and strangulated herniae because it prevents spasm of muscle and causes relaxation of the hernial ring.

Permanent interruption of the phrenic nerve may be a necessary procedure in the surgical treatment of partial thoracic stomach resulting from a congenitally short esophagus. However, I wish to emphasize that permanent interruption of the phrenic nerve is rarely necessary and should never be done in cases of hiatus hernia until it is definitely ascertained that it is not advisable to reestablish the function of the diaphragm. It should be emphasized also that this procedure cannot replace the operative repair of the hernia. It is important to bear in mind that the atrophy of the diaphragmatic muscle which follows permanent interruption of the phrenic nerve may make it impossible to obtain a satisfactory result in the event of further radical repair of the hernia.

## DIAPHRAGMATIC HERNIA

### RADICAL SURGICAL REPAIR

I prefer the abdominal approach in all cases of esophageal hiatus hernia because the herniated viscera are contained in a sac in the posterior mediastinum and do not enter the true pleural cavity. An oblique incision is made in the left rectus muscle and peritoneum, extending to the ensiform cartilage. The technical difficulties of adequate exposure of the esophageal hiatus are often considerable because of fixation of the left lobe of the liver to the leaf of the diaphragm. The exposure of the hiatus is greatly facilitated by cutting the suspensory ligament and retracting the left lobe of the liver to the right. This can be accomplished, when the left lobe is small, by folding it on itself, and when it is large, by retracting it forward into the incision. The spleen is often very adherent to the posterior part of the diaphragm and hernial opening but usually can be separated from these structures by blunt dissection. It is retracted posteriorly by a specially constructed retractor. In some instances the spleen may be almost drawn into the hiatus and may be so traumatized by separating it from its peritoneal attachments that its removal is advisable.

Herniae through the esophageal hiatus are true herniae and have an hernial sac consisting of abdominal peritoneum which is continuous with the serosa of the stomach. The attachment of the sac to the stomach must be separated and the sac must be either completely removed or permitted to retract into the posterior portion of the mediastinum. I believe that this is one of the most important technical considerations in the surgical treatment of this type of hernia.

After the sac has been removed, the enlarged defective esophageal hiatus is repaired by overlapping the margins of the opening. In many instances it is necessary to elevate the repaired hiatus to a higher position on the esophagus. The latter is a very important procedure in those cases in which there is any shortening of the esophagus or marked elevation of the esophagus into the thoracic cavity (Fig. 4). Repair is usually made to the left of the esophagus but in some cases it is necessary to repair the opening partially both to the right and to the left of the esophagus. In some instances the defect of the esophageal hiatus is posterior, extending to the spinal column. This type requires the overlapping of the margins posterior to the esophagus. In such cases, the condition is often thought to be a herniation through the aortic opening but extending over the aorta there usually is an imperfectly developed, fibrous band which is the margin of the defective esophageal hiatus. The closure is usually made with living sutures of fascia lata, which are removed from the thigh. The overlapped margins of the hernial opening are first stabilized with interrupted linen sutures. The fascia lata is then woven into the tissues by continuous suture and fixed in the tissues with interrupted linen sutures.

In many instances in which the stomach is incarcerated or obstructed, it is impossible to pass a stomach tube into the obstructed loculus of the stomach before operation. In these cases it is advisable to pass a stomach tube

soon after the abdomen is opened, directing the tube into the obstructed portion of the stomach in order to empty the gastric contents before any attempt is made to reduce the herniated viscera, because of the danger of regurgitation and aspiration of gastric contents into the lung. Before closure of the defective esophageal hiatus is completed around the lower part of the esophagus, it is important that a stomach tube of large caliber be passed through the esophagus into the stomach, to aid in the reconstruction of the normal esophageal opening and to prevent constriction of the esophagus by a tight closure. The loose areolar tissue or a small portion of the esophageal wall at the cardia is incorporated into the innermost margin of the closure by a suture of chromic catgut.

The abdomen always should be thoroughly explored for the presence of any other lesion, particularly of the stomach or gallbladder. In some cases it may be necessary to operate upon other associated lesions. However, I do not believe it advisable to carry out any additional surgical procedure at the time of repairing the hernia, unless it is imperative, but it is well to know whether the patient has gallstones or any other lesion in the upper part of the abdomen which might account for subsequent symptoms.

Inasmuch as the surgical treatment of this type of hernia is a repair of an abnormally large hiatus of the esophagus and not a complete closure of an abnormal opening, it is associated with a higher percentage of recurrences than any other type of diaphragmatic hernia, in fact, nine out of ten recurrences in the entire series of 404 cases were of this type of hernia. In four of the nine recurrences, symptoms were severe enough to require a second operation. There were seven deaths (2.2 per cent) in the 320 cases of esophageal hiatus diaphragmatic hernia.

*Congenital Short Esophagus.*—The surgical treatment of congenital short esophagus with partial thoracic stomach presents an entirely different technical problem from that of esophageal hiatus diaphragmatic hernia. As pointed out previously, the essential consideration in the surgical treatment of esophageal hiatus hernia is that of replacement of the herniated stomach into the abdomen, the removal or obliteration of the hernial sac and the repair and reconstruction of the esophageal hiatus accurately around the esophagus.

Congenital short esophagus with partial thoracic stomach is not a true hernia through the diaphragm, in that the stomach has never been in its normal position below the diaphragm because of shortening of the esophagus. The surgical problem in these cases is that of reconstructing the diaphragm over the elevated portion of the stomach; this can be accomplished if the shortening of the esophagus is not too great. By complete and permanent interruption of the phrenic nerve the diaphragm usually can be elevated from 2 to 5 cm. and then by complete separation of the attachment of the esophagus from the attachments around the esophageal hiatus, from 2 to 3 cm. of the esophagus can be drawn down into the abdomen. The elevation of the diaphragm and the pulling down of as much as is possible of the esophagus into the abdomen permit the esophageal hiatus to be closed around the lower

end of the esophagus, placing what was formerly the thoracic portion of the stomach below the diaphragm.

#### TRAUMATIC DIAPHRAGMATIC HERNIA

The causation of traumatic diaphragmatic hernia has been considered in an earlier section of this paper.

Traumatic diaphragmatic herniae usually do not present the difficult diagnostic problems which are associated with the esophageal hiatus type of hernia, for the occurrence of the injury leads one to suspect the possibility of a hernia being present. The symptoms associated with this type of hernia progress very rapidly, are severe, and are attributable to the mechanical interference with the function of the herniated viscera as well as to marked interference with function of the heart and lungs. This is due to the fact that there is no hernial sac and the abdominal viscera are in direct contact with the thoracic viscera. The condition in these cases may be more properly termed "evisceration of the abdominal organs into the pleural cavity" rather than a "true hernia." The most marked immediate symptoms are usually those of respiratory and circulatory embarrassment. These herniae are more frequent in adult life and the compensatory cardiac and respiratory reserve usually carries the patient over the acute symptoms if the other associated injuries have not been too great. Later, severe hemorrhage from the gastro-intestinal tract may occur as a result of incarceration or strangulation of the hollow viscera. If the patient survives the acute condition, the later symptoms depend on the viscera involved. The symptoms may consist of obstinate constipation, the occurrence of large quantities of gas in the colon and attacks of partial or complete intestinal or gastric obstruction. The sudden onset of symptoms in cases of traumatic hernia usually is related directly to the injury and there is rarely a question as to the clinical diagnosis. Surgical treatment is demanded because of the danger of cardiac and respiratory failure or because of intestinal strangulation (Fig. 5).

Those types of diaphragmatic hernia which result from inflammatory necrosis of the diaphragmatic muscle caused by subdiaphragmatic abscess or pressure from the drainage tubes used for drainage of empyematic cavities, are considered as traumatic herniae. The symptoms associated with these herniae are often somewhat obscure and in many instances they are unrecognized for a long period of time because the possibility of a hernia is not considered and the symptoms are often thought to be due to the primary illness. In some instances the hernia does not occur in these cases for many months after the patient recovers from the primary illness.

The surgical approach to these herniae may be through the thorax or through the abdomen. For all herniae through the right side of the diaphragm, I prefer the thoracic approach because the large right lobe of the liver interferes with the exposure of the right side of the diaphragm if the abdominal approach is used. In herniae of this side the right lobe of the liver is often incorporated in the hernia and its reduction is more safely accomplished

through the thoracic approach than through the abdominal approach because there is less danger of hemorrhage from injury to the liver.

In all traumatic herniae through the left side of the diaphragm, I prefer the abdominal approach through an oblique left rectus incision. The herniated viscera are usually very adherent to both the abdominal and the thoracic side of the diaphragm and to the structures within the thorax. The adhesions



FIG. 5a and b.—Patient, age 73. Large left traumatic diaphragmatic hernia due to an automobile accident. Herniation of the entire stomach, transverse colon and spleen and of several feet of small bowel. The esophagus is in normal position.

c. Same patient three and one-half weeks after repair of laceration in the posterior portion of the left diaphragm which did not involve the esophageal hiatus. The entire stomach is in normal position below the diaphragm.

to the margins of the opening and to the under surface of the diaphragm are often very marked and should be separated first. The adhesions to the structures within the thoracic cavity are separated from below upward by approaching them through the hernial opening. By the abdominal approach this can be accomplished with little danger of injury to the abdominal or thoracic viscera, because the definite relationship of the herniated structures can be established.

In cases in which there has been considerable loss of structure or in which the muscle has been torn from its attachment to the thoracic wall, the defect in the diaphragm should be repaired by fascia lata stabilized with linen sutures. I believe this to be the most satisfactory type of closure in all these cases. In cases of traumatic hernia in which the laceration is confined to the dome of the diaphragmatic muscle, it usually is advisable to repair the opening by lapping the anterior margin over the posterior margin of the opening. When possible, it is advisable to overlap the margins of the opening from 2 to 3 cm. In those cases in which the laceration splits the muscle of the esophageal ring, great care should be taken in repairing the esophageal hiatus. In those cases in which the laceration extends to the margin of the thorax and in which the attachments of the diaphragm are torn from the thoracic wall, the repair is made not only by overlapping the laceration of the leaf of the diaphragm but by resuturing the diaphragmatic muscle to the thoracic wall. This can be accomplished by suturing the diaphragmatic muscle to the intercostal muscles between the ribs. When possible, the diaphragmatic muscle should span two interspaces, being fixed to the intercostal muscles with fascia lata and stabilized with interrupted linen sutures.

In a few instances the relaxation of the diaphragmatic muscle caused by interruption of the phrenic nerve will not be sufficient for repair of the defect. In these cases the diameter of the thorax must be narrowed by resecting the lower ribs by thoracoplasty. It is usually not necessary to resect more than a few inches of the eighth, ninth and tenth ribs at the angles.

Before the abdomen is closed, the herniated viscera should be thoroughly explored, to be certain that there has been no injury to a viscus and that there are no bands of adhesions which will interfere with the function of the abdominal viscera. In cases in which there has been considerable obstruction of the large bowel, it may be necessary to perform appendicostomy or colostomy at the time of operation.

In the series of 55 cases of traumatic diaphragmatic hernia there were no recurrences, and four deaths.

#### CONGENITAL DIAPHRAGMATIC HERNIAE DUE TO MALFORMATION AND STRUCTURAL DEFICIENCIES

Congenital diaphragmatic herniae may occur in either the right or the left side of the diaphragm but are much more common through the left side than through the right. The more common herniae of this type are those



through the pleuroperitoneal hiatus, those due to the lack of formation of the posterior portion of the diaphragm and those through the foramen of Morgagni (Larrey's space), anteriorly, more accurately termed subcostosternal herniae.

In the first two types there is rarely, if ever, an hernial sac and the abdominal viscera are in direct contact with the thoracic viscera. In the third type (subcostosternal) there is always an hernial sac, which consists of peritoneum and parietal pleura.

The symptoms of congenital types of diaphragmatic hernia due to structural deficiency in the formation of the diaphragm usually involve multiple abdominal viscera and are often similar to those noted in association with the traumatic types of hernia, as there is rarely a confining sac and the herniated abdominal viscera are in direct contact with the thoracic viscera. The symptoms in these cases are often more severe than those noted in cases of traumatic hernia. Because of the occurrence of the hernia at birth, the respiratory and cardiac symptoms are usually the most severe owing to the marked unilateral alteration in intrathoracic pressure and the occurrence of this derangement of intrathoracic pressure at a time at which the compensatory respiratory and cardiac reserve has not been developed to a sufficient degree to maintain function of these organs. Many infants born with these congenital defects die in the first few hours or days of life. However, if the respiratory and cardiac mechanisms are able to compensate for the presence of these abdominal viscera in the thorax, these patients may live on to childhood or even to adult life without any great amount of disability or symptoms, provided that intestinal or gastric obstruction does not develop. There is less likelihood of obstruction developing in these cases than in the cases of traumatic hernia because there are usually fewer adhesions between the abdominal viscera and the thoracic viscera in the former than in the latter. When the stomach is involved in these herniae, it usually becomes markedly dilated and these patients often have symptoms of partial gastric obstruction. Intestinal obstruction may occur owing to bands of adhesions between the omentum and loops of bowel or owing to inflammatory conditions of the bowel. Inasmuch as there is usually a nonrotation of the right portion of the colon and the cecum, and the appendix is in the left thoracic cavity, appendicitis may develop and produce a very serious hazard to life.

In the surgical treatment of these herniae the approach in the first two types may be either thoracic or abdominal but I prefer the abdominal approach through an oblique left rectus incision. In the third type (substernal) the approach should always be through the abdomen and usually through an oblique right rectus incision or a transverse incision in the epigastrium. I prefer the oblique right rectus incision.

*Pleuroperitoneal Hiatus Herniae.*—These herniae occur in the posterolateral portion of the diaphragm and are due to failure of fusion of the pleuroperitoneal membrane and the septum transversum. The defect is usually triangular with the apex toward the median portion of the diaphragm.

## DIAPHRAGMATIC HERNIA

The defect usually extends to the thoracic wall but occasionally there is an imperfectly developed band of muscle tissue extending along the thoracic wall. These herniae do not have an hernial sac and there is a direct communication between the abdominal and the thoracic cavity.

The most common abdominal viscera involved in this type of hernia are the colon and the small bowel. There may or may not be herniation of the



FIG. 6a and b.—Patient, age four months. Pleuroperitoneal hiatus hernia with herniation of many loops of large and small bowel in the left thoracic cavity. Marked displacement of the mediastinum and heart to the right. The stomach is dilated and below the diaphragm.  
c. Same patient on reexamination one year after operation. The stomach and the intestines are entirely below the diaphragm, which is of normal contour and position. The heart and the mediastinum are in normal position. Both pulmonary fields are normal.

spleen and stomach. There is often a failure of rotation of the colon and the entire right side of the colon (appendix and cecum), the terminal part of the ileum and all of the small intestines to the jejunum are involved in the hernia.

This type of hernia is said to be the most common of the congenital types of hernia due to structural deficiencies. These herniae are present at birth. Many of the infants suffering from them die in the first few hours or days of life because of respiratory and cardiac embarrassment and before surgical intervention can be instituted. In treating those infants who are able to survive in spite of the altered intrathoracic pressure and thoracic visceral relationship, surgical intervention should be instituted as soon as possible because of the danger of intestinal obstruction. If they are able to maintain nourishment, it is well to delay operation for two to three months in order to permit some development of their accessory respiratory mechanism. If operation is delayed for a long period, the abdominal viscera will have lost their right of residence in the abdomen in that the abdominal cavity will not have developed sufficiently to contain them and there will be marked increase in the intra-abdominal pressure when the viscera are replaced into the abdomen (Fig. 6).

In repair of the smaller herniae of this type the opening can be closed without utilizing interruption of the phrenic nerve. On the other hand, in repair of the larger herniae interruption of the phrenic nerve is a necessary procedure. The opening is completely closed by overlapping the margins from 2 to 3 cm. If the patient is an infant, this closure is made with interrupted silk sutures. Before the opening is completely closed, the air is aspirated from the pleural cavity by inserting a catheter connected to a suction apparatus. At the time of withdrawal of the catheter the last suture is tied, completely closing the communication between the thorax and the abdomen.

One of the chief dangers associated with the repair of these herniae is marked alteration of intrathoracic or intra-abdominal pressure. It is very important in these cases that the respiratory function be maintained by positive pressure during the operation and that at the completion of the operation negative pressure be obtained and secured in the thoracic cavity. A roentgenogram should be taken at the completion of the operation to see that there is no shift of the mediastinum due to the pneumothorax. I do not permit the patient to leave the operating table until I have seen the roentgenogram. If there is any shift of the mediastinum, more air is withdrawn to maintain the mediastinum in the midline.

In the series of nine cases of hernia through the pleuroperitoneal hiatus there were no recurrences and three deaths.

*Congenital Absence of the Posterior Portion of the Diaphragm.*—This type of hernia is due to failure of the formation of that portion of the diaphragm which is derived from the pleuroperitoneal membrane. The defect is in the posterolateral portion of the diaphragm and usually extends from the eighth rib posteriorly and medially to the esophageal hiatus. These

herniae usually do not have a sac but there may be an imperfectly developed enveloping membrane of peritoneum and omentum which simulates a sac. These herniae may be considered an enlargement of the foregoing pleuro-peritoneal type in that the essential difference is a much more extensive congenital defect in the formation of the diaphragm. There are more abdominal viscera involved in the hernia in that these herniae always contain the stomach and spleen as well as the large and small bowel. Occasionally the left kidney is elevated above its normal level into the pleural cavity (Fig. 7).

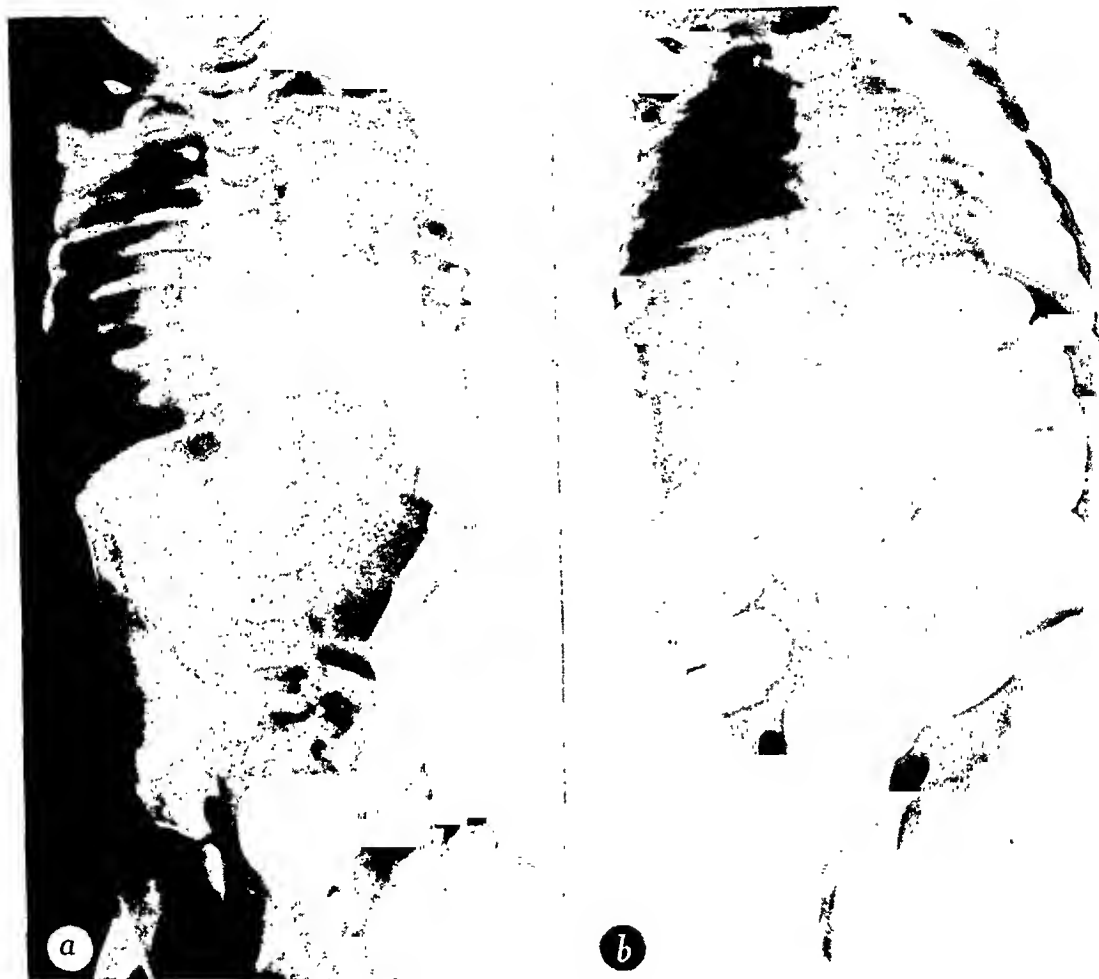


FIG. 7a.—Patient, age six months. Congenital absence of a portion of the diaphragm. Herniation of the entire right portion of the colon and cecum (small bowel and stomach), into the left thoracic cavity. Complete collapse of the left lung. Marked displacement of the heart and mediastinum to the right.

b. Same patient one month after reconstruction of the defective diaphragm (with fascia). Entire colon (and other herniated viscera) below the diaphragm. The left diaphragm, the heart and the mediastinum are in normal position. Pulmonary fields normal.

Not only do the surgical problems associated with these herniae involve all of the problems of the pleuroperitoneal herniae as far as altered intra-abdominal and intrathoracic pressure is concerned but in addition there is the problem of closing this large gap with the diaphragmatic muscle that is present and of reconstructing the attachment of the diaphragmatic muscle to the thoracic wall. In some instances the posterior perirenal fascia may be utilized in obtaining this closure and fixation to the thoracic wall. If the

gap is not too great, this can be accomplished by complete, permanent interruption of the phrenic nerve. If the defect is too large to permit the relaxed diaphragm to span this gap, it is necessary to shorten the diameter of the diaphragm by extrapleural rib resection.

In 12 cases herniae were due to congenital absence of a portion of the diaphragm. There were one recurrence, and two deaths.

*Subcostosternal Hernia through the Foramen of Morgagni (Larrey's space).*—Herniation of abdominal viscera through regions of deficiency of muscle in the anterior portion of the diaphragm close to the sternum has received various names, such as diaphragmatic hernia through the foramen of Morgagni, or through Larrey's fissure or space, and also substernal, retrosternal, parasternal or anterior diaphragmatic hernia. Inasmuch as these herniae usually occur to either side of the anterior midline of the diaphragm, if an anatomic term is to be used, it would be preferable to designate them as subcostosternal diaphragmatic herniae.

There is some difference of opinion as to whether these herniae should be classified as congenital or acquired herniae. It is impossible to explain their occurrence on a basis of faulty fusion or improper disposition of the embryonic mesodermic elements which go to form the diaphragm, as this anterior portion of the diaphragm is derived from the septum transversum only. But the consistency of the location of the hernial opening, the fairly constant relation of the neck of the hernial sac to the round and falciform ligaments of the liver and the frequency with which the hernial sac protrudes into the right side of the thoracic cavity at the same point of entrance at the cardiophrenic angle, as well as the often associated nonrotation of the right portion of the colon, all strongly suggest a fundamental embryologic basis for these herniae. These herniae are essentially direct herniae through a congenital defect in the structure of the diaphragm or a faulty attachment of the diaphragm to the sternum and costal cartilages. The constant presence of a peritoneal sac shows that the peritoneum had closed off the abdominal cavity from the pleural cavity before the actual herniation of the abdominal viscera occurred.

Subcostosternal diaphragmatic hernia is one of the two types of diaphragmatic hernia, in my experience, which have an hernial sac. The other type of diaphragmatic hernia which has an hernial sac is that through the esophageal hiatus. It is interesting that subcostosternal hernia is probably the rarest type of diaphragmatic hernia and esophageal hiatus diaphragmatic hernia is the most common; both are essentially congenital in origin but are rarely present at birth, and occur in most instances in later life because of increased abdominal pressure on a congenitally defective diaphragm.

The abdominal viscera usually involved in the hernia are the colon, omentum, ileocecal coil and rarely the stomach (Fig. 8).

The subjective symptoms associated with these herniae are often indefinite and depend on the type and amount of abdominal viscera involved in the hernia. They are usually due to impairment of respiration and intestinal

obstruction. Among them are dyspnea, cough and attacks of partial intestinal obstruction and thoracic and abdominal pain.

In the cases in which hollow viscera are involved in the hernia, symptoms occur which suggest the possibility of a hernia or at least the necessity of a roentgenologic examination of the intestinal tract which will determine whether a hernia is present. The cases in which omentum only is involved in the hernia present a much more difficult clinical problem in arriving at a

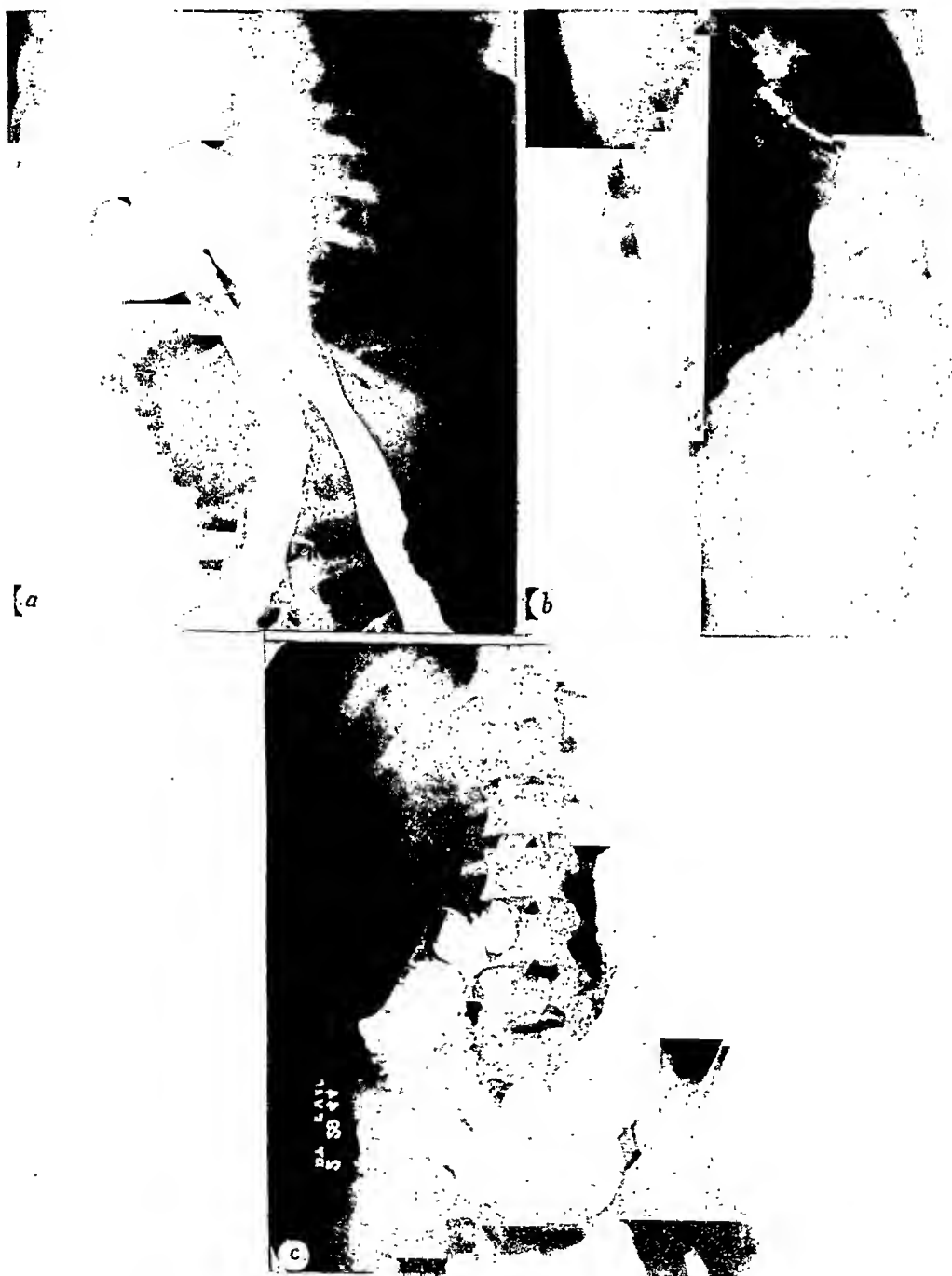


FIG. 8a and b.—Patient, age 35. Subcostosternal (foramen of Morgagni) diaphragmatic hernia. Herniation of transverse colon with marked displacement of splenic and hepatic flexures into the right anterior thoracic cavity at the cardiophrenic angle.

c. Same patient one month after repair of hernial opening in the anterior diaphragm. The entire colon is below the diaphragm.

definite diagnosis. The subjective symptoms in the latter group are entirely thoracic as a result of mechanical interference with respiration and expansion of the lungs. These symptoms suggest a primary pulmonary lesion and direct the clinical investigation to roentgenologic study of the thorax. The roentgenologic findings of an increased density in the pulmonary field justify the clinical diagnosis of a primary intrathoracic lesion which may be thought to be an intrathoracic tumor. This erroneous clinical diagnosis is particularly likely to occur if there are no subjective symptoms even to suggest that an abdominal condition may be present and, even though the gastro-intestinal tract is examined roentgenologically, no lesion is demonstrated as no abdominal hollow viscera are involved in the hernia.

One of the most important clinical considerations of this type of hernia is the possibility of regarding the patient's condition as due to an intrathoracic tumor in the cases in which the omentum is the only abdominal structure involved in the hernia.

The treatment of these herniae is surgical closure of the abnormal opening in the diaphragm after replacement of the abdominal viscera into the abdomen. I prefer an abdominal approach through the upper part of the right rectus muscle because the opening in the diaphragm is very accessible and the abdominal contents of the hernia are more safely and easily reduced from the abdominal than from the thoracic side of the diaphragm as the true relationship of the herniated viscera to the hernial sac can be accurately determined.

The method of closure of the neck of the sac and of the defect in the structure of the muscle of the diaphragm depends on the size and character of the opening. Small linear openings may be closed by overlapping the margins. Larger transverse openings extending beneath the sternum are best closed by suturing the anterior margin of the diaphragmatic muscle defect to the posterior sheath of the rectus muscle and to the anterior thoracic wall.

The most satisfactory material for closure of the opening is living suture of fascia lata removed from the thigh and stabilized in the tissues with silk. The round ligament of the liver can be incorporated in this closure to strengthen it as well as to reestablish its position on the anterior abdominal wall.

The closure of the large openings is facilitated by paralyzing the right side of the diaphragm by temporary interruption of the right phrenic nerve. This procedure, however, is not necessary in the closure of small openings. Preparation can be made to interrupt the phrenic nerve in the supraclavicular region after exploring the opening and determining whether or not interruption is necessary.

In this series of 404 cases of diaphragmatic hernia, eight were of the subcostosternal type. There were no deaths or recurrences following their operative treatment.

In Table II the surgical procedures and operative results in the entire series of 404 cases are given.

# CONGENITAL DIAPHRAGMATIC HERNIA\*

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IN REVIEWING the literature of the past ten years on congenital diaphragmatic hernia, one is as impressed by the number of single cases reported by various authors as well as by the series of cases, such as those of Harrington,<sup>7</sup> Ladd and Gross,<sup>12</sup> and Hartzell,<sup>8</sup> and Truesdel,<sup>15</sup> Many of these cases have been operated upon successfully at an early age. It is obvious from these reports that the diagnosis is made much earlier and that the operative treatment has made great progress in recent years. In 1925, Hedbloom reported that 75 per cent of congenital herniae died before they were one month old. In 1938, I reported ten cases from the Babies Hospital, six of whom had been operated upon. The purpose of this paper is to review the surgically-treated cases of the first series, add to their follow-up, and to report 11 additional cases operated upon since 1938.

It is still difficult to estimate the incidence of congenital diaphragmatic hernia because of the dissimilar reports, but the percentage of cases found in a given number of roentgenologic examinations seems to be steadily increasing. Bradley, from the Mayo Clinic, reported the occurrence as 1 in 18,000 cases. In 1920, MacMillan found only three cases in 15,000 roentgenologic examinations, and in 1924, Pancoast and Boles reported 16 cases in 9,000 gastro-intestinal series. In 1938, Dickson reported 206 cases during a 14-year period from the Toronto General Hospital. I am quite sure that the condition occurs much more frequently than has been suspected.

The most common congenital defects in the diaphragm are, in order of their occurrence: (1) Esophageal hiatus. (2) Foramen of Bochdalek. (3) Foramen of Morgagni. (4) Defects in the dome. Herniae through the vena caval or aortic openings in the diaphragm have never been reported.

## EMBRYOLOGY

The complexity of the embryonic development of the diaphragm predisposes it to congenital defects, most of which result from the failure of fusion of the component fibers at various points. The defects in the dome of the diaphragm are more difficult to explain from an embryologic standpoint other than to say that they are due to a failure of fusion at this point. The embryonic diaphragm consists of two parts: a ventral part which is the cephalic portion of the septum transversum, developing in the cervical region; and a dorsal part which is the pleuroperitoneal membrane, developing from the lateral body walls and destined to become the closing membrane between the pleural and the peritoneal cavities. The muscular portion of the diaphragm develops while it is in the cervical region from the third and fourth cervical myotomes on each side. During development, the diaphragm migrates from the region of the third cervical vertebra to its final location opposite the

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\* This article was to have been presented before the Annual Meeting of the American Surgical Association, May, 1945.



twelfth thoracic vertebra, and, during this migration, its plane of direction changes many times. It is thought that the original communication between the pleural and peritoneal cavities closes about the third month of intra-uterine life. If this communication remains open, there is formed the pleuroperitoneal hiatus known as the foramen of Bochdalek. Since the liver lies over the right foramen, herniae occur more often on the left than on the right side. Failure of fusion of the costal and sternal fibers at either side of the sternum results in the formation of the foramina of Morgagni. The defects in the dome are more common on the left side. Hernia through the esophageal hiatus has been attributed either to the failure of development of the diaphragm at that point, or to the failure of migration of the stomach because of a short esophagus. These herniae usually have a peritoneal sac. While herniae through the esophageal hiatus and through the foramen of Morgagni usually have a peritoneal sac, herniae through the foramen of Bochdalek usually do not, and defects in the dome of the diaphragm may or may not include one.

#### SYMPTOMOLOGY

The symptoms of diaphragmatic hernia may be either circulatory, respiratory, gastro-intestinal, or a combination of all three. They are due to mechanical interference with the function of the herniated structures or to interference with respiratory or circulatory organs upon which the herniated structures encroach. In most of the cases of hernia through the foramen of Bochdalek, the usual finding is that the chest is full of intestines, both large and small, often accompanied by part of the stomach and, quite frequently by the spleen and kidney. The symptoms in such cases are quite sure to be cyanosis, dyspnea, nausea, vomiting and signs of incomplete intestinal obstruction. On the other hand, it is surprising to find how few symptoms some of these patients have even though many of the abdominal structures are in the chest. One patient in this series had a little difficulty breathing during the hot weather; another had been perfectly well, and the diaphragmatic hernia was discovered during a routine physical examination. One patient had failed to gain weight as rapidly as normal; another had a cough, diarrhea and tarry stools for several weeks. As the symptoms vary to such a marked degree, the diagnosis of diaphragmatic hernia should always be considered when patients exhibit perplexing upper abdominal, respiratory or cardiac symptoms.

#### DIAGNOSIS

The diagnosis of diaphragmatic hernia may be made easily from a roentgenogram of the chest, which will show the presence of gas bubbles, collapsed lung and displacement of the heart away from the affected side. The roentgenologic examination has probably been the greatest factor in the discovery of many diaphragmatic herniae. If opaque media are used, it is not only possible to identify the herniated structures, but a lateral view of a barium enema will demonstrate whether the defect in the diaphragm is in front of or behind the liver. Without roentgenograms, the diagnosis will

often be missed since the physical signs may be confusing, and vary with the number of abdominal structures in the chest. Many cases of diaphragmatic hernia have been diagnosed as dextracardia, congenital heart, pneumonia, empyema and tuberculosis. To prove how confusing the physical signs may be; without roentgenograms of the chest, I would like to cite the difficulties in the diagnosis of one of the cases reported here. When I saw the patient first, she was two years old and had "lung trouble since birth." She had just completed a four-month period of bed rest because the parents were told that she had "adult type of pulmonary tuberculosis." Many other diagnoses had been made, such as empyema, unresolved pneumonia, *etc.*, and her chest had been explored with a needle 15 times. She had been seen by a number of doctors but had never had a roentgenogram taken of her chest. Her last physician heard signs in the chest which he interpreted as being due to the presence of intestinal coils and had a roentgenogram taken which confirmed his diagnosis.

#### TIME FOR OPERATIVE INTERVENTION

Operative repair is the only relief for this condition. I agree with Dr. Ladd, who has stated that these cases should be operated upon as quickly as possible after the diagnosis is made. We have followed his example in many of our cases, operating as soon as we felt reasonably sure the baby could tolerate it. Recently, we have taken two babies to the operating room in Davidson beds, which provide oxygen, as neither of them could be kept out of oxygen for more than a few moments. They were anesthetized, an intra-tracheal catheter introduced, and the operation proceeded without the least difficulty. When the chest contains either small or large intestine, the operation should be performed immediately as such patients are apt to develop intestinal obstruction which is a most unfortunate complication, as we found in one of our early cases (Case 3). While attempting to improve this baby's condition which was too poor to stand operation, he developed a high intestinal obstruction. He had to be operated upon at once since his obstruction was high in the jejunum, and, at operation, the distended loops were the last ones to be removed from the chest. He died 12 hours after his operation in spite of high concentration of oxygen, transfusions, *etc.* Another reason for not delaying operation is that the abdomen will not develop while the structures are allowed to remain in the chest, and when the structures are returned to the abdomen, it will be too small to receive them. We had this unfortunate experience in one of our cases who had had symptoms of diaphragmatic hernia since birth but was not operated upon until he was nine years of age.

#### OPERATIVE PROCEDURE

There is a difference of opinion as to whether the operative approach should be through the chest or the abdomen. Many cases reported in the literature have had both abdominal and thoracic incisions and often a combined thoraco-abdominal incision has been used. I prefer an abdominal approach through a subcostal incision, and have used it in all cases. In one

recurrent case, it was necessary for us to make a thoracic incision in addition to the abdominal incision. It has always seemed to me to be easier to reduce the structures by gentle traction from below than by forcing them down from above. The abdominal approach also lessens the possibility of postoperative respiratory complications and gives the operator an opportunity to replace the abdominal structures in about their normal positions. As a rule, there are no adhesions present in the chest unless the case is one of long standing, and the structures usually are easily reduced if the operator places a retractor in the diaphragmatic defect and equalizes the pressure in the chest and abdomen before he tries to reduce the structures. If he does not do this, he will find that the intestines will be sucked back in the chest about as fast as one can reduce them. Mattress sutures of silk should be used for repair of the defect overlapping the edges if possible.

In three cases of this series, while the defect was in the posterior part of the diaphragm, it differed considerably from hernia through the foramen of Bochdalek. There was a large opening, no attachment of the diaphragm to the posterior chest—probably a deficiency of the diaphragm. In these cases, I used a row of silk sutures with two needles on each, passing them through the diaphragm to the outside of the chest wall, one on either side of the adjacent rib and tied outside over a piece of gauze. Due to the deficiency of reparative material in these cases, the above row of sutures in closing the defect attached the diaphragm at a higher level in the chest than normal. A second row of continuous or interrupted silk then attached the edge of the diaphragm to the pleura and intercostal muscle. In any type of closure, a catheter is placed in the chest and the air removed before the last suture is tied. It is also desirable to have the phrenic nerve where it can be easily crushed if necessary. It has been our custom to expose the phrenic nerve in the neck a day or two before the repair, placing a traction suture about it so that it can be drawn out and crushed, if desired, during the repair of the diaphragm. We have done this in most of our cases except in the very young babies who were in bad condition. This exposure of the phrenic nerve is unnecessary, of course, if the thoracic approach is used. Intratracheal or positive-pressure anesthesia are desirable.

The difficulties of operation depend upon the location and size of the defect and upon the presence of adhesions. The mortality depends to a large extent upon the age of the patient.

#### POSTOPERATIVE CARE

All patients should be placed in an oxygen tent immediately after operation, and should be kept there for several days. The oxygen relieves abdominal distention, decreases both the respiratory efforts of the baby and the possibility of postoperative respiratory infection because of the easy regulation of the tent's temperature. Fluid requirements should be met by parenteral methods. In many cases, we have used a continuous intravenous drip to supply glucose and saline. Pleural effusion may occur and should be watched for, the chest being aspirated if necessary.

CASE REPORTS

GROUP I—HERNIA THROUGH THE FORAMEN OF BOCHDALEK

Case 1.—P. N., male, 4.5 months old, was admitted to the Babies Hospital, October 11, 1930, having had difficulty in breathing during the hot weather. He had had a convulsion 24 hours before admission, but was well otherwise. Roentgenologic examination showed small intestine in his left chest.

*Operation.*—The abdomen was opened through a left subcostal incision revealing a hernia through the left foramen of Bochdalek. His chest contained all of the small intestine beyond the duodenojejunal juncture, all the colon to a point beyond the splenic flexure, and the spleen. The splenic flexure was adherent to the parietal pleura, and was brought down after mobilization. All structures were reduced, and the diaphragmatic opening was closed with mattress sutures of black silk, the edges of the hiatus being overlapped. The patient was kept in an oxygen tent and had a continuous intravenous drip of saline for several days postoperative. His convalescence was uneventful.

Follow-up: Six and one-half years postoperative the child was normal in every way.

Case 2.—S. D., female, six months old, was admitted to the Babies Hospital, November 13, 1931, having vomited during the preceding five days. Her birth was full-term by cesarean section, and she had gained steadily, with no illness previous to the present one. She was well-developed and well-nourished. A gastro-intestinal series showed small and large intestine in the right chest.

*Operation.*—November 20, 1931: The abdomen was opened through a right subcostal incision. On retracting the liver from the diaphragm, a patent foramen of Bochdalek was revealed behind it. The chest contained the third and fourth parts of the duodenum, all the small intestine, and all the large intestine as far as the midtransverse colon. The structures were reduced, and the opening closed with mattress sutures of black silk. Convalescence was uneventful.

Follow-up: Roentgenologic examination six years postoperative showed the lung expanded and all abdominal structures below the diaphragm. The child has been very well.

Case 3.—M. B., male, age five weeks, was admitted to the Babies Hospital, January 6, 1936, with a history of vomiting and cyanotic episodes for two days. "Was developing well until two days ago when he collapsed, turned blue and had rapid respirations." He had had a similar spell 24 hours before admission. He had been delivered by cesarean section. Roentgenologic examination showed the right chest filled with small intestine. While under observation, the patient developed a high intestinal obstruction and was immediately operated upon.

After isolation of the phrenic nerve in the neck, a right subcostal incision was made. A large, posterolateral defect was found in the diaphragm through which practically all of the small intestine had herniated into the chest. A definite obstruction, due to a kink, was found in the upper jejunum. The opening in the diaphragm was closed with mattress sutures of black silk. The patient was placed in an oxygen tent immediately after operation, but he died 12 hours later as the result of shock.

There was no choice but to operate upon this case. A palliative operation could not be performed because of the high intestinal obstruction. This is a serious complication, and one which may happen in any case where there is either small intestine or colon in the chest. This patient also had an umbilical hernia, bilateral cryptorchidism, penile hypospadias, hypertelorism, and a pilonidal sinus.

Case 4.—E. C., male, age ten months, was first admitted to the Babies Hospital, in 1924, with a history of vomiting and convulsions. Roentgenologic examination showed

the whole left chest filled with small intestine. He was discharged but was readmitted several times subsequently, with signs of an intestinal obstruction. Each time he was taken home against advice, when his obstructive symptoms had disappeared. He was finally admitted, when eight years old, with obstructive symptoms, at which time his parents consented to an operation.



FIG. 1.—Autopsy specimen of hernia through the left foramen of Bochdalek. Small and large intestine in the left chest. Heart displaced to the right, both lungs compressed by the herniated structures.

*Operation.*—April 25, 1932: The abdomen was opened through a left subcostal incision, which revealed a patent, left foramen of Bochdalek as well as a defect in the left dome. The left chest contained all of the small intestine from the duodenojejunal juncture on, all of the colon to a point beyond the splenic flexure, and the spleen. The structures were removed from the chest after a very tedious dissection. Both openings in the diaphragm were closed with mattress sutures of silk. The structures could not be returned to the abdomen because they had never been there before, and the cavity was not large enough to contain them. The child's condition was desperate in spite of a transfusion and an infusion on the operating table. His condition was so precarious that the defects in the diaphragm were reopened and the viscera replaced into the chest. The patient died three hours postoperative.

He should have been operated upon earlier in life, as his abdomen was not sufficiently developed to contain the viscera removed from his chest.

Case 5.—N. G., female, age seven months, was admitted to the Babies Hospital, October 31, 1938, complaining of cyanotic attacks since birth. Roentgenograms showed left diaphragmatic hernia. Phrenic nerve was exposed in her neck two days before the hernia repair.



FIG. 2.—Hernia through the left foramen of Bochdalek before operation.

*Operation.*—This disclosed a left foramen of Bochdalek hernia. The left chest contained part of the stomach, most of the small intestine, the splenic flexure of the colon and the spleen. The defect in the diaphragm was closed with mattress sutures of black silk. Her convalescence was uneventful.

*Follow-up:* It is not 6.5 years postoperative, and the child is normal in every way.

Case 6.—V. D., male, age three weeks, was admitted to the Babies Hospital March 7, 1941. Weight 5,000 Gm. Cyanotic attacks since birth. Roentgenograms showed left

diaphragmatic hernia. The phrenic nerve was exposed in the neck two days before operation.

*Operation.*—A left foramen of Bochdalek hernia was found, with the left chest containing part of the stomach, several loops of small intestine, the colon as far as the splenic flexure and the spleen. The defect was repaired with mattress sutures of silk. Convalescence was uneventful.

*Follow-up:* Lost to follow-up after 1.5 years, at which time he was perfectly well and developing normally.



FIG. 3.—Same case three weeks after operation. All abdominal structures below the diaphragm.

**Case 7.**—J. B., female, age six days, was admitted to the Babies Hospital suffering from cyanotic episodes which were so severe that she was placed in oxygen 24 hours after birth. Roentgenograms showed a left diaphragmatic hernia.

*Operation.*—Age of 14 days: There was present an hernia through the left foramen of Bochdalek, with the left chest containing all of the small intestine, and the colon as far as the descending colon. The defect was closed with mattress sutures of black silk. Convalescence was uneventful. Discharged 19th day postoperative.

*Follow-up:* Three and one-half years later: She is well, and a roentgenogram of chest normal.

**Case 8.**—P. T., female, age 11 days, was admitted to the Babies Hospital suffering from cyanotic episodes since birth. Some attacks lasted several hours. Roentgenograms

of the chest showed left diaphragmatic hernia. The phrenic nerve was isolated two days before the repair of the hernia.

*Operation.*—Age of 22 days: Exploration showed that the left chest contained all of the small intestine, cecum and transverse colon through the left foramen of Bochdalek. The defect was closed with mattress sutures of silk. Convalescence was uneventful. Discharged 15 days postoperative.

*Follow-up:* Three years and nine months after operation: She is perfectly well. The roentgenogram of chest is normal.

*Case 9.*—D. K., male, age seven days, was admitted to the Babies Hospital with a history of severe cyanotic episodes since the fourth day of life. He had been kept in an oxygen tent most of the time since then. Vomited bile-stained fluid on several occasions in the past three days. A roentgenogram showed right diaphragmatic hernia. For the next ten days, he could not be taken out of oxygen long enough to be fed. After this, his condition improved considerably.

*Operation.*—Age three weeks, weight 2,550 Gm. Taken to the operating room in Davidson bed (oxygen), anesthetized and an intratracheal catheter inserted. At operation, a right foramen of Bochdalek hernia was found. The right chest contained all of the small intestine and the colon as far as the midtransverse colon. The defect was closed with mattress sutures of black silk. Convalescence was uneventful except for slight wound infection. Discharged on 21st day postoperative.

*Follow-up:* It is not 15 months postoperative; and he is in excellent condition, with no recurrence.

#### GROUP II—LARGE POSTERIOR DIAPHRAGMATIC DEFECTS

##### *No Attachments of Posterior Diaphragm to Chest Wall, Deficiency of Diaphragmatic Leaf*

*Case 1.*—A. E., male, age five months, was admitted to the Babies Hospital, March 13, 1934, with a history of dyspnea and cyanosis since birth. Roentgenologic examination showed small and large intestine herniated into the chest through a defect in the right diaphragm.

*Operation.*—The abdomen was opened through a right subcostal incision, and disclosed a defect in the posterior half of the right diaphragm, which corresponded to about one-half the size of the entire right leaf. Closure seemed impossible. The structures in the chest consisted of all of the small intestine beyond duodenojejunal junction; the cecum; the appendix and right half of the transverse colon; and the right kidney. All viscera were, however, reduced, and the defect closed with considerable difficulty. Convalescence was uneventful. The patient remained free from symptoms for about one and one-half years, when a routine roentgenogram of his chest, October 29, 1935, showed a recurrence.

*Second Operation.*—Age 2.5 years: Twenty-four hours before repair, under avertin anesthesia, the right phrenic nerve was exposed in the neck, a loop of plain gut placed about it for traction, so that it could be readily identified and crushed if necessary. Under ether anesthesia, 24 hours later, the scar of the right subcostal incision of the previous operation was excised, and the abdomen opened. Practically all of the structures that were in the chest at the time of the first operation had reherniated into it. There were many adhesions present, and reduction of contents necessitated considerable dissection. In order to close the defect, a right intercostal incision was made through the eighth space, which greatly facilitated the closure of the diaphragmatic defect. The phrenic nerve was then crushed from within the chest. Closure was accomplished with mattress sutures of black silk. The patient developed pneumonia and pleural effusion in the right chest postoperatively; 275 cc. of sterile fluid was removed from the right chest upon two occasions.

*Follow-up:* It is now eight years since the operation for recurrence of the hernia. He is entirely well, and the roentgenogram of the chest is normal.



Case 2.—P. J., female, age six days, was admitted to the Babies Hospital, April 25, 1944. She was one of twins, the daughter of a physician. Her twin brother was perfectly normal. The chief complaint was cyanosis and dyspnea since birth. First cyanotic attack occurred shortly after birth, and she seemed to become cyanotic every time her position was changed. A roentgenogram showed gas bubbles in the left chest.

*Operation.*—Age of 13 days; intratracheal anesthesia: There was a large defect in the posterior part of the left diaphragm with no attachment of the diaphragm to the chest wall. The left chest contained part of the stomach, all of the small intestine and the colon as far as the splenic flexure. The diaphragmatic defect was closed by passing silk mattress sutures out through the chest wall and tying them about the ribs. The only way the defect could be closed was to attach the diaphragm higher in the chest wall. Several interrupted silk sutures attached the edge of the diaphragm to the parietal pleura and intercostal muscle. Convalescence was uneventful. Discharged on the 18th postoperative day, weighing 200 Gm. more than her admission weight.

Follow-up: Admitted to the Babies Hospital three months after discharge with signs of intestinal obstruction. Roentgenograms showed no recurrence of the diaphragmatic hernia, but did show distended loops of jejunum. At operation, an obstruction was found in the upper jejunum due to adhesive bands. These were released, and her convalescence was quite uneventful. It is now more than one year since the closure of the diaphragmatic hernia and she is doing very well.

Case 3.—G. O., female, age two years, 11 months, was admitted to St. Luke's Hospital, May 24, 1937. She had not been well from birth, and was said to have always had lung trouble. Treated for pertussis for a long time because of cough. Diagnosis of pneumonia (unresolved), empyema, and later, "adult-type of Tb." Had had four months of bed rest. Her chest had been explored with needle 15 times. She had never had a chest roentgenogram.

*Operation.*—Large, left posterior diaphragmatic defect, with peritoneal sac, found. Her left chest contained stomach, all of the small intestine, the colon as far as the splenic flexure, and the spleen. The defect was closed with mattress sutures passed to the outside, with sutures of diaphragm higher in the chest wall. Convalescence was uneventful. Roentgenogram of chest seven years postoperative shows everything normal.

### GROUP III—ESOPHAGEAL HIATUS HERNIA

Case 1.—L. Y., female, age six months, was admitted to the Babies Hospital, June 22, 1931, with a history of loss of weight and vomiting for three months. She was a pale, undernourished child, whose roentgenologic examination showed her stomach and transverse colon herniated into her chest through the esophageal hiatus. She continued to vomit while under observation for two weeks. The vomitus contained blood on several occasions.

*Operation.*—July 8, 1931: The abdomen was opened through a right subcostal incision. The entire stomach, the first and second portions of the duodenum, and almost all of the transverse colon were found to be in the chest, having herniated through a large esophageal hiatus. The viscera were reduced, and the esophageal hiatus was closed tightly around the esophagus after a large stomach tube had been passed. It was evident at operation that the esophagus was short, as it was only with considerable traction on the stomach that it could be kept in the abdomen. Convalescence was uneventful.

Follow-up: Roentgenologic examination, three months later, showed that a small portion of the stomach had reherniated into the chest. The patient has not been examined during the past year, but was doing well when last heard from.

This was about the result we expected in this case. At least operation kept duodenum and transverse colon from reëntering the chest.

## CONGENITAL DIAPHRAGMATIC HERNIA

### GROUP IV—HERNIA THROUGH THE FORAMEN OF MORGAGNI

**Case 1.**—R. D., male, age 16 months. Weight 6,050 Gm. Shortness of breath since two months of age. Had always been a feeding problem. Mongolian idiot. Roentgenograms showed colon in the chest through the foramen of Morgagni.

*Operation.*—This showed presence of bilateral hernia through the foramen of Morgagni. Right hernia contained right lobe of liver, the ascending colon and half of the transverse colon. Left hernial sac was empty. Right hernia only was repaired. Died nine days postoperative from pneumonia.

**Case 2.**—J. V., male, age 12. Fatigue of one year's duration. Shortly after birth it was noticed that this child was mentally and physically retarded. Taken thyroid extract O. D. since infancy. Mental development approached normal but he was small for his age, very shy, and slow of speech. He was operated upon in another hospital two months ago for an acute appendicitis and a diaphragmatic hernia was discovered. B.M.R. was —28. Roentgenograms showed hernia through the foramen of Morgagni containing transverse colon.

*Operation.*—June 20, 1944: Bilateral hernia through the foramen of Morgagni. Peritoneal sacs removed and bilateral defects closed with mattress sutures of black silk. Convalescence was uneventful.

Follow-up: Entirely well 11 months postoperative.

### GROUP V—EVENTRATION OF THE DIAPHRAGM

**Case 1.**—D. J., female, age one month. Normal delivery but was difficult to resuscitate, and was put in oxygen tent immediately after birth. Was too ill for the mother to see for the first four days of life. Discharged from the maternity hospital at age of ten days doing very well. Admitted to Babies Hospital with no symptoms. Roentgenologic diagnosis of diaphragmatic hernia made. After a period of convalescence during which she continued to gain weight she remained free from symptoms and was allowed home for a period of five weeks because she had blepharitis and conjunctivitis, and possibly a congenital heart.

*Operation.*—Age three months: Operation performed at Babies Hospital on October 20, 1941. Right subcostal incision disclosed eventration of the diaphragm. The right and left lobes of the liver as well as the stomach and part of the colon were above the normal diaphragmatic level. Only meager diaphragmatic muscle fibers were found and it was quite obvious that no surgical repair could be effected. It was also thought that the condition was compatible with life since there was no danger of obstruction of the structures. Discharged 13 days postoperative.

Follow-up: Developing normally, doing very well to date.

### GROUP VI—CONGENITAL ABSENCE OF HEMIDIAPHRAGM

**Case 1.**—E. H., age three months; weight 4,230 Gm., was admitted to Babies Hospital with a history of cyanosis and dyspnea since birth. Normal spontaneous delivery, baby breathed normally. Noticed cyanosis next day. Roentgenograms upon admission showed abdominal structures in the left chest, and displacement of the heart.

*Operation.*—Left subcostal incision showed large stomach in left chest, spleen, jejunum, part of the left lobe of the liver also. No muscular diaphragm. Baby died three days after operation. Autopsy showed perforation of the stomach and necrosis of the left lobe of the liver. There was no muscular diaphragm but the left chest showed a large sac containing the stomach, jejunum, left lobe of the liver and the spleen. The perforation of the stomach was thought to be terminal, probably the result of volvulus. The baby also had hypertrophy of the myocardium, with a patent foramen ovale.

### SUMMARY

1. Congenital diaphragmatic hernia occurs more often than was formerly suspected, and it should be ruled out in all cases showing obscure chest and upper abdominal symptoms.

2. The symptoms of congenital diaphragmatic hernia vary a great deal. They may be either cardiac, respiratory, gastro-intestinal, or a combination of all three.

TABLE I

TABULATION OF RESULTS IN 17 CASES

Male	Female	Age in Weeks	Cured	Died	Cause of Death
Bochdalek Herniae (9)					
Right—3					
2	1	5, 24, 1	2	1	Preoper. intestinal obst.
Left—6					
2	3	18, 2, 28, 8, 1	5		
Also Defect in Dome (1)					
1		9 years		1	Shock
Large Posterior Defects					
Right (1) Left (2)					
1		26 weeks	1 (recurrence)		Cured
	1	1 week	1		
	1	3 years	1		

## OTHER TYPES

Esophageal hiatus:	Female	6 mos.	Cured	Minimal recurrence
Morgagni:	Male	16 mos.	Died	Postoper. pneumonia (Mongolian idiot)
	Male	12 yrs.	Cured	
Eventration:	Female	3 mos.	Surviving	
Congenital absence:	Male	3 mos.	Died	Perforation of stomach. Liver necrosis

3. The diagnosis may be made by a roentgenogram of the chest, which shows gas bubbles in the place of normal lung, collapsed lung and displacement of the heart away from the affected side.

4. Physical signs in the chest are often so confusing that the diagnosis may be missed if a roentgenogram is not taken.

5. Surgical repair of the hernia should be advised immediately for all cases where either small or large intestine is in the chest because of the danger of intestinal obstruction.

6. The author prefers the abdominal approach through a subcostal incision, with exposure of the phrenic nerve in the neck 48 hours before repair. Many surgeons prefer the thoracic approach.

7. Positive pressure or intratracheal anesthesia are very desirable.

8. All patients should be kept in an oxygen tent for several days after operation.

9. Fluid requirements should be maintained after operation.

10. Pleural effusion may occur, and the chest should be aspirated as is necessary.

11. Seventeen cases of congenital diaphragmatic hernia which were operated upon have been reported.

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# IDIOPATHIC DILATATION OF THE ESOPHAGUS\*

## DIFFERENTIATION OF CLINICAL TYPES AND SUCCESSFUL OPERATION IN INTRACTABLE CASES

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TODAY it is recognized that dilatation of the esophagus without obvious pathologic cause is a common condition. In fact, it has approximately one-third the frequency of carcinoma of the esophagus, being second only to the latter in the statistics of the larger clinics (MacMillan<sup>1</sup>). It appeared earlier in the literature under the purely descriptive terms, ectasia or idiopathic dilatation of the esophagus. But today the author's etiologic conception is usually introduced into the name and this condition is most commonly designated as achalasia of the cardia or as cardiospasm, though there are still widely conflicting opinions about the cause of the dilatation. Fortunately for the patients who suffer from this serious, and usually progressive, difficulty in the passage of food from the dilated esophagus into the stomach, treatment does not need to wait for a final determination of cause; by dilating the cardia, either on one or repeated occasions, the symptoms in the majority of cases are adequately controlled. However, some of these patients do not respond satisfactorily to this and the other conservative measures of treatment. Although the percentage of this refractory group is small this failure to respond to conservative measures offers a serious problem for two reasons: First, because of the complete failure of the usual therapeutic measures to alleviate the condition; and, secondly, because of the progressive seriousness of their symptoms. They constitute a small but important group of cases, and their relief has become a challenge to the general surgeon as well as to the esophagoscopist.

In studying the problem presented by these cases of idiopathic dilatation of the esophagus not adequately controlled by conservative measures, certain observations have been made that I believe help: (1) To clarify our understanding of the mechanism involved; (2) to subdivide these resistant cases into clinical types which show important physiologic and probably etiologic differences; and (3) to attack the difficult therapeutic problem involved.

The first clinical description of idiopathic dilatation of the esophagus was found by Dr. Ralph Major,<sup>2</sup> and included in his collected classic descriptions of disease. This case was described by Thomas Willis in his *Pharmaceutica Rationalis*, published in London, in 1674. This great seventeenth century physician was, like his contemporary Thomas Sydenham, an accurate and

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painstaking observer of clinical manifestations. Not only did he give an excellent description of the characteristic symptoms, but in addition to this he established the principle of treatment by instrumental dilatation, and even forecast the persisting conflict of opinion as to whether or not the primary cause is a disturbance of the extrinsic nervous mechanism in the region of the cardia. Little was added to our knowledge concerning this condition for another two hundred years, during the latter half century of which isolated cases were reported as pathologic and clinical oddities. Thus, in 1876, Zenker and Ziemssen<sup>3</sup> were able to collect only 18 cases, not including Willis's case, of 1674, and a case particularly well described by Purton,<sup>4</sup> in 1821. It is to the clinical work of Mikulicz<sup>5</sup> and the experimental work of Meltzer<sup>6</sup> that we owe the conception and even the name of cardiospasm as the first major step toward establishing the mechanism and etiology of the dilatation. This theory had a rather general acceptance until certain serious objections were raised to it. To Hurst<sup>7</sup> we owe chiefly the hypothesis that the difficulty in the passage of food from the dilated esophagus into the stomach is not due to spasm but is caused by the failure of relaxation to occur in the terminal portion of the esophagus when the advancing peristaltic wave reaches it. In conformity with this conception he coined the term "achalasia" of the cardia. Hurst felt that the ease with which dilators passed through the esophagus into the stomach was incompatible with the conception of spasm of the cardia, as was also the absence of hypertrophy of the circular muscle at this point upon necropsy. Another difficulty that is faced by any theory based on abnormality of the nervous mechanism of the cardia, whether cardiospasm or achalasia, is to explain why the dilatation of the esophagus usually ends not at the cardia but above that point, approximately at the level of the diaphragmatic hiatus; also why, in the human, no important condensation of the circular muscle acting as an anatomic sphincter can be found at the cardia. The best answer to these objections is found in the experimental production of cardiospasm by cutting both vagus nerves in animals.<sup>8,9</sup> This demonstrates the presence of a broad physiologic sphincter sufficiently powerful not only to produce the typical dilatation of the lower esophagus but actually to cause the death of the animal from failure of food to pass into the stomach. The theory of achalasia has been considerably bolstered by microscopic findings of pathologic changes in the myenteric plexus at the lower end of the esophagus. Rake<sup>10</sup> first convincingly demonstrated these lesions, and they have been confirmed by other observers,<sup>11</sup> although there are some typical cases that have failed to show such changes.<sup>12</sup> (A possible explanation of these exceptions is that the involvement of the vagus tract may be at any point from the brain to the terminal nerve plate.) Although it has not been definitely proved that such degeneration of the ganglion cells in Auerbach's plexus is primary rather than secondary, probably this theory of achalasia of the cardia is today the most widely accepted hypothesis of the etiology of idiopathic dilatation of the esophagus. However, there are important opinions still adverse to it.

Jackson,<sup>13</sup> on the basis of a very extensive observation of these cases through the esophagoscope, believes that the obstruction to the esophagus is due to phrenospasm, while Mosher<sup>14</sup> feels that the cause is a peri-esophageal fibrositis at the hiatal portion of the esophagus. An excellent review of the literature to that date was presented by Sturtevant<sup>15</sup> in 1933.

This, in brief, is the present status of our knowledge concerning the etiology of idiopathic dilatation of the esophagus. Nearly all of the investigators who have contributed recent studies of the condition have assumed that the clinical syndrome is regularly due to some one fundamental cause, though they have varied among themselves as to what this cause is. If other physical conditions appeared to operate in individual cases, then they were considered to be secondary factors which had arisen to complicate the picture during the lengthy course that is usually characteristic of this condition. As the result of observations made in the cases cited below, correlated with certain facts already recorded in various places in the literature, we believe that such an assumption of a single basic etiology is fallacious and that the characteristic clinical syndrome is caused by several entirely different primary causes. It is important to differentiate these various fundamental types, both to obtain a better understanding of this frequent disease, and also for the practical assistance that it affords in the management of the intractable group.

#### CLINICAL OBSERVATIONS

Hurst's conception of an achalasia of the cardiac end of the esophagus due to some abnormality in its vagal innervation is accepted in this study as the most plausible explanation in the majority of cases for the esophageal dilatation and for the difficulty that is observed in the passage of material into the stomach. Our first case to throw doubt on the universal applicability of this theory was the following:

**Case 1.**—C. K., a 65-year-old paperhanger, was admitted to the hospital, September 15, 1927, on account of dysphagia and regurgitant vomiting associated with dull aching distress of three months' duration. Even the swallowing of water may now cause regurgitation. The dysphagia increased in severity and he had lost 22 pounds in weight in the last three months. Fifteen months before the onset of these persistent symptoms, he had had an attack of sharp noncharacteristic epigastric pain radiating around both sides to the back and lasting three weeks. The only physical findings of significance on examination were evidence of malnutrition with recent weight loss and moderate dehydration. His blood picture was that of a moderate secondary anemia. His roentgenologic examination showed a typical moderate dilatation of the esophagus with peristaltic waves and ending in a smooth cone at approximately the level of the diaphragm (Fig. 1). Esophagoscopy verified the dilatation of the esophagus, but due to the fact that only the short esophagoscope was being used, the terminal cone of the esophagus was not visualized at this time. In view of the patient's emaciation, a gastrostomy tube was placed in the stomach transabdominally. The operative incision was so short that no exploration was feasible, except that no gross malignancy of the stomach was felt on palpation with one finger. Feedings through the gastrostomy tube quickly rectified the patient's nutritional deficiency when repeated roentgenologic examinations and esophagoscopy (with 53-cm. scope) verified the diagnosis of dilatation of the esophagus without obvious cause. Repeated dilatation of the cardia (with the

FIG. 1

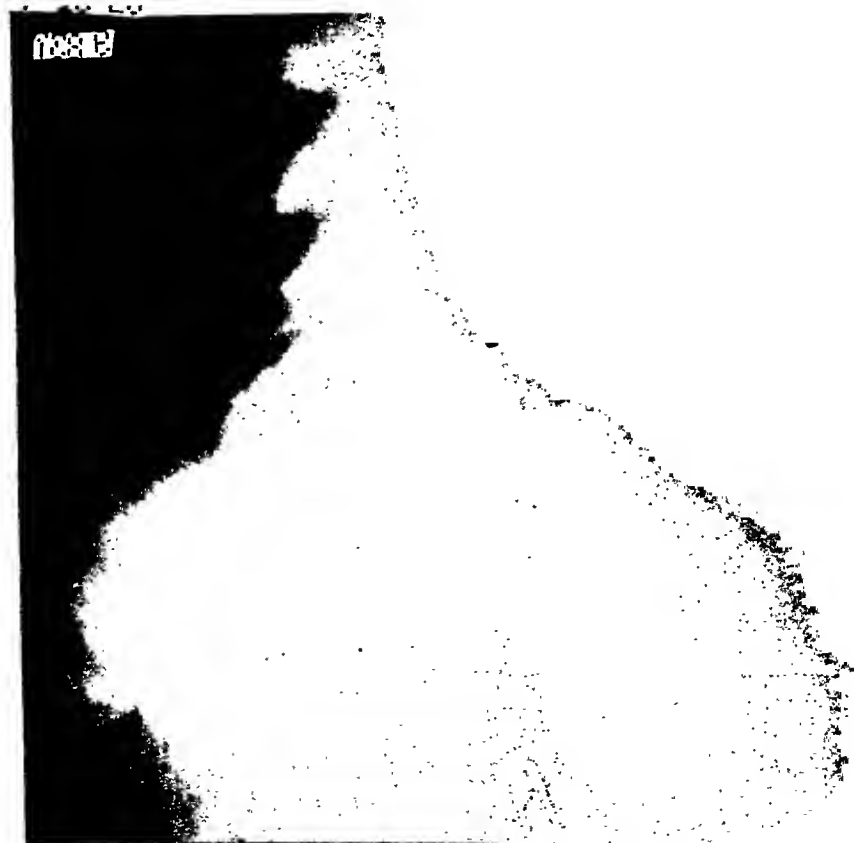


FIG. 2

FIG. 1.—Case 1: Dilatation of the esophagus found on first examination August 1, 1927, proven later to be cardiospasm apparently reflex from an ulcer of the stomach.

FIG. 2.—Case 1: Showing dilatation of the esophagus still present ten months later but now also accompanied by a pylorospasm, patient being fed entirely by gastrostomy tube.



large-size Plummer dilator) caused temporary improvement in the ability to swallow food, which benefit, however, lasted only for a few days each time, and the dysphagia always returned. On this account, the gastrostomy opening was not allowed to close and most of the feeding had to be given by tube. About ten months after the gastrostomy was performed, he developed severe pain in the epigastrium after tube feedings, accompanied by huge peristaltic waves in the stomach. Roentgenologic examination of the stomach merely verified the delay in its emptying without demonstrating any cause for this. It was obvious that the patient now had a pyloric obstruction or spasm in addition to the persistent cardiospasm (Fig. 2). The symptoms of both continued with periods of exacerbation and remission for another ten months when the pain and difficulty in giving sufficient food either by mouth or by tube necessitated an abdominal exploration. An ulcer of the stomach was found on the lesser curvature of the stomach a little beyond the incisura angularis. There was no obstruction either at the cardia or the pylorus. A subtotal gastrectomy was carried out, including about two-thirds of the lesser curvature. The antecolic anastomosis between the end of the stomach and the side of the jejunum (Pólya-Moynihan type) did not come near to the cardia. Almost immediately after operation the patient's ability to swallow food by mouth began to improve so that by the seventh postoperative day, he was taking solid foods without difficulty and the gastrostomy tube was removed. The gastrostomy opening healed slowly (it had been maintained for 21 months) and during the time it remained open he still had some dysphagia.

*Subsequent Course:* Since the closure of the gastrostomy fistula (now 11 years) the patient has not had any further major difficulty in the swallowing of his food. The eating of very dry food occasionally causes a sticking sensation and he has, on a few occasions, regurgitated a mouthful or so of food. He is particularly apt to be quite constipated at such times. Two months after gastrectomy roentgenologic examination showed "on ingestion of liquid barium suspension there was scarcely any delay in the lower esophagus. The barium passed through the cardiac sphincter in a more or less continuous stream. The marked obstruction previously noted had disappeared and, at the most, there was only a very slight temporary delay. On ingestion of barium cereal paste the delay was more pronounced, though it passed through without being regurgitated." And two years following gastrectomy roentgenologic examination of the esophagus showed no evidence of dilatation and no delay in the passage of the barium mixture into the stomach.

COMMENT: In this case, the syndrome of idiopathic dilatation of the esophagus was present with its well-marked symptomatology and the characteristic roentgenographic appearance. This syndrome disappeared after the resection of a gastric ulcer. It is extremely difficult to explain such a sequence of events by the hypothesis of achalasia (as opposed to cardiospasm). It seems quite clear that the dilatation of the esophagus occurred chiefly in response to a reflex disturbance (presumably sympathetic stimulation), which in this case caused spasm of the cardia first and later also an associated spasm of the pylorus.

This case with its lasting relief following removal of the focus of reflex irritability suggested that possibly information of value might be obtained by temporary paralysis of the sympathetic innervation to the cardia while the vagus innervation is not disturbed. It was hoped that we might be able to achieve this result by spinal anesthesia, just as we have previously used this procedure to subdivide cases of megacolon.<sup>16</sup> The efferent sympathetic

pathways to the cardia seem to be very complex<sup>17</sup> and there is no exact knowledge of the precise levels at which they leave the cord. Therefore, when this investigation was begun it was uncertain whether or not anesthesia would be a helpful tool of investigation in it. The following case is the first one that presented itself to us to determine this point:



FIG. 3.—Case 2: Spasm of the lower third of the esophagus.

Case 2.—H. G., a 56-year-old man, came into the hospital in February, 1929, on account of dysphagia. His symptoms came on rather suddenly two years ago when he had difficulty in swallowing a piece of bread; it seemed to him as if something closed in his throat and he regurgitated the bread. Since then he has had similar difficulty in swallowing masticated solid foods unless he “washes them down” with *warm* fluids. Even with this assistance it seems to stop for an interval near the stomach before it feels as if it goes into this viscus. Sometimes even with the regimen of slow eating followed by warm fluid he has to vomit because the food will not pass. He can drink hot liquids readily but he has not been able to tolerate cold water since the onset of his illness. It feels as if the latter “stops right in the pit of the stomach” and then he regurgitates the water. The dysphagia has been progressive, particularly in the last few months when he has been having great difficulty in getting the food into the

stomach, during which time he breaks out into a hot sweat and following the lengthened meal he feels exhausted. He has lost 20 pounds during the course of the illness but seems to be maintaining his weight at present. One year previously he was examined by Dr. Chevalier Jackson who dilated his lower esophagus. Following this his symptoms were much less marked but this improvement lasted for only two weeks. Two other dilatations were followed by very little benefit. Medication with belladonna was also ineffective. In his past history he had two attacks of acute epigastric pain which suggested gallbladder disease to several physicians but a cholecystogram did not afford



FIG. 4A



FIG. 4B

FIG. 4.—Case 2: Release of spasm of the lower third of the esophagus by spinal anesthesia (A) 25 minutes after intraspinal novocaine injection, immediately after ingestion of barium. (B) 30 minutes after intraspinal novocaine injection and five minutes after ingestion of barium. The spasm in the lower third of the esophagus has completely disappeared after the induction of spinal anesthesia.

any definite corroboration of such, although one surgeon advised cholecystectomy. Also, he had two attacks of pain suggestive of renal colic with hematuria a year ago but investigation of his upper urinary tract by a competent urologist failed to disclose any definite pathology there and no stones were visualized roentgenologically. These symptoms have not recurred.

Physical examination revealed a moderate hypertension with possibly a slight enlargement of the heart to the left. There was no particular tenderness at any point in the abdomen. The Wassermann reaction in the blood was negative.

Roentgenologic examination revealed no abnormality in the passage of the barium mixture through the upper esophagus, but the lower third of the esophagus showed multiple gross areas of spastic contraction which held the barium in segmental accumulations and greatly retarded its progress through this region. There were at least seven or eight constrictions in the lower esophagus though their configuration was constantly changing (Fig. 3). When the barium got through this contorted portion in the lower esophagus it passed through the cardia into the stomach without further delay.

Under fluoroscopic control, a Plummer bag was drawn down into the area of spasm along a silk thread, and expanded to a water pressure of 18 to 20 pounds for five minutes without discomfort. This dilatation was repeated twice more at weekly intervals,

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but as with the previous course of dilatations the improvement in symptoms was only ephemeral.

The effect of various drugs and spinal anesthesia on the spasm of the lower esophagus was then studied. Atropine and ephedrine produced no striking change in the spasm and intensive treatment with tincture of belladonna produced no improvement in symptoms. On the other hand, the effect of spinal anesthesia was very striking. Anesthesia was obtained to the level of T-8 and well-marked hypo-esthesia to T-4.



FIG. 5

FIG. 5.—Case 3: Dilatation of the esophagus control film.



FIG. 6

FIG. 6.—Case 3: Dilatation of the esophagus entirely disappears during spinal anesthesia.

There was no marked fall in blood pressure. During the height of the anesthesia the spasm of the lower esophagus disappeared almost completely and the delay in the emptying of the esophagus into the stomach was greatly diminished (Fig. 4).

COMMENT: It had been hoped that the temporary interruption of this spasm in the lower esophagus might lead to a gradual improvement in symptoms as we have succeeded in obtaining in instances of Hirschsprung's disease.<sup>18</sup> However, the patient was lost track of soon after this and we do not know whether there was any therapeutic influence of the spinal anesthesia on the later course of the disease. Telford and Simmons<sup>19</sup> have reported one case with an excellent clinical result following a spinal anesthesia.

The result in this first case, although it was one of persistent spasm involving the lower third of the esophagus (like those reported by Schmidt<sup>20</sup>) and not a typical one of idiopathic dilatation, led us to believe that we could achieve by this means a satisfactory paralysis of the sympathetic nerves to the lower esophagus. We, therefore, used spinal anesthesia as a method of

investigation in typical instances of idiopathic dilatation of the esophagus and found that such cases could be divided into two groups: (A) Those that respond by temporary relief of the dilatation; and (B) those that show no marked improvement after satisfactory spinal anesthesia to the level of the sixth thoracic segment. The following case is a typical example of Group A:

**Case 3.**—J. P., a 36-year-old factory worker came into the hospital on account of dysphagia of three months' duration. He first noted a sticking sensation on eating solid food, often associated with moderately sharp, somewhat crampy pain. On account of this difficulty in swallowing solid foods he has had to confine himself practically to a liquid diet, and he has lost 25 pounds in weight. Liquids usually pass quite freely if he drinks slowly. *Past History:* During the last year he has had a few attacks of sharp epigastric pain radiating to the right shoulder. In the present illness this radiation seems to have been associated with the difficulty in swallowing. Also, for the past two years he has had some frequency of bowel movement with mucous shreds.

Physical examination was essentially negative throughout, except for evidence of moderate weight loss. The patient is of a rather nervous temperament. Routine laboratory studies were negative, except for a positive guaiac reaction in a liquid stool. Roentgenologic examination showed a fusiform dilatation of the lower esophagus with a marked delay in the passage of barium from the lower part of the cone which was perfectly smooth (Fig. 5). There was some irregularity in the filling of the duodenal cap. However, it was difficult to get enough barium into the stomach for satisfactory examination. An oral cholecystogram showed an agglutination of small calcified masses in the fundus of the gallbladder, with good concentration of the dye and normal emptying. Esophagoscopy examination showed considerable retention in a moderately dilated esophagus without much maceration of the mucous membrane. Just below the level of the diaphragm there was a small superficial ulceration noted on the posterior wall and there was some reddening of the mucous membrane. Just below this the lumen was reduced to a small opening which failed to relax with bougie dilatation so that only a small tip could be forced into the stomach. There was no evidence of malignancy. Spinal anesthesia was carried out, which was complete to T-7. Immediately after anesthesia was attained the dilatation and stasis in the esophagus entirely disappeared and the barium mixture passed without delay into the stomach (Fig. 6). A diagnosis of cardiospasm, probably secondary to cholelithiasis was made, and the patient was explored. In addition to multiple amorphous stones in the gallbladder the patient had an ulcerated lesion on the midposterior wall of the stomach suggesting carcinoma, with extensions involving the posterior peritoneum above the pancreas. The cardia of the stomach itself was not grossly involved. Due to the posterior peritoneal involvement, however, the lesion was inoperable.

**COMMENT:** In this case spinal anesthesia demonstrated that dilatation of the lower esophagus and the dysphagia which it produces can be temporarily overcome in certain instances by paralysis of the sympathetic innervation to the level of the sixth thoracic segment. The following two cases, however, show instances of typical idiopathic dilatation of the esophagus where satisfactory spinal anesthesia does not produce any striking change in the condition:

**Case 4.**—F. S., a 25-year-old housewife, came into the hospital, September 29, 1938, on account of dysphagia. The difficulty in swallowing began rather gradually about seven months previously, and has been increasing since that time. In attempting to swallow she has a painful, choking feeling and then regurgitates her food, which relieves this sensation. At times she is even unable to keep water down. For a time after the

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FIG. 7



FIG. 8



FIG. 9

FIG. 7.—Case 4: Dilatation of the esophagus control film.

FIG. 8.—Case 4: Dilatation of the esophagus not relieved by satisfactory spinal anesthesia.

FIG. 9.—Case 4: Postoperative result. Dilatation of the esophagus has been entirely relieved by esophagogastrostomy.

onset of the symptoms she thought by taking soft solids that she was able to swallow more readily. Now, however, she thinks that it makes little difference what she eats. She is constantly regurgitating both solid food and liquids. There is some fluctuation in the severity of the dysphagia. She has lost 17 pounds from her original weight of 110 pounds. Beginning two months after the onset of her symptoms she had several esophageal dilatations. The first of these afforded her a considerable relief of symptoms which lasted, however, for only a few days and the subsequent dilatations have been even less effective. She is thoroughly discouraged by the difficulty that she has in swallowing food and by its apparent progressive course, recently having more trouble in even getting liquids down. Her past history and system review appears to be entirely negative as far as relevant data is concerned. She had uncomplicated pneumonia at the age of 15.

Her physical examination shows evidence of recent weight loss but otherwise is negative. Routine laboratory studies, including blood Wassermann, are negative. Roentgenologic examination showed a typical, well-marked dilatation of the esophagus ending in a smooth cone at approximately the level of the diaphragm (Fig. 7). Esophagoscopy had to be carried out under general anesthesia as the patient refused to allow it under local. The esophagus showed marked dilatation even of its upper portion and it contained much retained food and mucus. After evacuation of its contents the lower end was examined. The dilated cone ended in a constricted area which would allow only a rather small esophageal bougie to pass. It was dilated as well as possible with bougies as the Plummer bag would not pass the contracted zone. Considerable relief was obtained following this dilatation, which improvement lasted, however, for only three days. After the initial dilatation this patient had six further dilatations, the dilatation being carried out to the point where at one time the esophagoscope could be passed into the stomach. After each dilatation she had temporary improvement which disappeared within only a few days, and it was impossible to make the patient gain weight. Spinal anesthesia was given on two occasions as a test of motor function. At the first time the level of anesthesia was unsatisfactory, complete anesthesia being obtained only to about T-11. At the second time, however, anesthesia was obtained to the level of T-6 and hypoesthesia two or three segments above this point. In spite of an entirely satisfactory anesthesia the dilatation of the esophagus remained practically unaltered (Fig. 8). It was thought that there might be possibly a slight improvement in the passage of barium into the stomach. This, however, was not striking. The test was interpreted as showing that satisfactory spinal anesthesia in this instance did not materially influence the dilatation and the stasis in the esophagus.

**Case 5.**—E. P., a 78-year-old retired nurse, came into the hospital, May 25, 1939, on account of dysphagia and vomiting of five months' duration. A short time before the onset of these symptoms she had contracted a cold, associated with a sense of tightness in her chest, which kept her in bed for ten days. Since then she has had a persistent, rather unproductive cough and has felt fatigued. The difficulty in keeping food and vomiting began at that time and has progressed since then so that she now vomits a considerable part of the food she takes. About three weeks prior to admission she began having severe paroxysms of substernal distress relieved only by vomiting. She has identified unaltered food eaten as long as 24 hours previously. She has lost 20 pounds in weight during the present illness. Eight years ago the patient had severe pains in the chest during meals, accompanied by a feeling that the food did not pass freely into the stomach. These attacks occurred two or three times a week and persisted in a modified form until two years ago when they disappeared after taking dilute hydrochloric acid with every meal.

*Past History:* She has had some palpitation of the heart with orthopnea for ten years, for which her physician has given her digitalis. Fifteen years ago she had a bleeding duodenal ulcer, for which a gastro-enterostomy was carried out together with the removal of a gallbladder containing stones.

On physical examination the patient was a well-preserved woman for her age, but she showed evidence of rather marked weight loss. There were fine râles at both lung bases. A soft, blowing systolic murmur at the apex of the heart. The abdomen contained no masses and there was no tenderness. Wassermann reaction in the blood was negative. There was albumin without casts in the urine, and on admission a white count of 18,000, with 77 per cent polymorphonuclear leukocytes. The Wassermann



FIG. 10.—Case 5: Dilatation of the esophagus with compound "S"-shaped curve and fluid level in the upper portion of the "S." This is idiopathic dilatation of the esophagus of the dolicho-esophagus type.

reaction in the formed stool was negative. Roentgenologic examination showed a greatly dilated and very tortuous esophagus in the shape of an "S" with the upper pouch extending to the right of the midline. The esophagus then rises toward the left, makes a hairpin turn and comes down again just to the right of the midline. The dilated portion ends perfectly smoothly at approximately the level of the diaphragmatic hiatus (Fig. 10).



The major portion of the barium mixture given was still in the esophagus at the end of six hours. Esophagoscopy showed marked retention of cloudy fluid and food particles with a typically pasty-looking mucous membrane at the level of the diaphragm. The mucous membrane folds lie in apposition to each other but offer no resistance to the passage of the esophagoscope through the cardia. Three dilatations of the cardia gave little or no relief. In spite of this treatment combined with other conservative measures, such as esophageal lavage, atropine, *etc.*, it was impossible to get sufficient nourishment for her. A satisfactory spinal anesthesia was given (complete to the level of T-7) without marked benefit either to the patient's ability to swallow or to the dilatation of the esophagus. Possibly barium got through from the lower pouch into the stomach slightly more easily.

COMMENT: In Cases 4 and 5, then, satisfactory spinal anesthesia produced no striking change in two typical examples of idiopathic dilatation of the esophagus. These, therefore, fall into our Group B, in which sympathetic overactivity apparently plays no rôle in the production of the syndrome, while Cases 1, 2, and 3 fall into Group A, where the esophageal abnormality is apparently on the basis of sympathetic overactivity. Unfortunately, we have not yet had an opportunity to examine the reaction to spinal anesthesia in simple cases of idiopathic dilatation of the esophagus which respond readily to dilatation.

#### CLINICAL TYPES

From an analysis of our series of 85 cases of idiopathic dilatation of the esophagus (usually diagnosed as achalasia of the cardia or as cardiospasm), and aided by the information obtained from the use of spinal anesthesia as a tool of investigation, we feel that it is now possible to recognize four different clinical types which probably also differ from each other in their etiology. These types are: (1) Achalasia of the esophagus; (2) true cardiospasm; (3) dilatation associated with a constriction at, or just above, the cardia; and (4) dolicho-esophagus. Let us investigate separately each of these clinical groups.

1. *Achalasia of the esophagus* is probably the most common variety encountered. It usually readily responds to dilatation of the esophagus and is due to an incoördination of the neuromuscular apparatus at the lower end of the esophagus, whereby the cardia fails to relax properly. At present, there are no pathognomonic criteria clinically of such a failure of relaxation and, consequently, the diagnosis of this type must be made largely by exclusion of the other three types, though probably most of the cases of idiopathic dilatation of the esophagus that respond promptly to simple dilatation and whose symptoms are readily controlled by this method fall in this category.

2. *True Cardiospasm*: The roentgenographic appearance in this clinical type appears identical to that seen in achalasia. However, in this clinical syndrome, a reflex focus of irritation can be found, the eradication of which will largely or completely remove the difficulty in the passage of food from the esophagus into the stomach. Such cases respond to spinal anesthesia with temporary relief. During the anesthesia, the free passage of barium

into the stomach can be seen under the fluoroscope. Probably the most frequent foci for the origin of the reflex causing the cardiospasm are ulcer of the stomach or duodenum, other irritated lesions involving the posterior peritoneum, and cholelithiasis.

3. *Dilatation Associated with Constriction at the Cardia*: This group probably represents a small percentage of the cases of idiopathic dilatation of the esophagus. Our fourth case, however, seems to be definitely a member of this group. At operation, a circular fibromuscular band was found around the region of the cardia and the lumen of the latter would not admit a lead pencil. There was no evidence of any recent acute inflammatory reaction associated with this fibrosis. Whether this was fibrositis due to peri-esophagitis as Mosier hypothecates or whether a congenital abnormality somewhat like hypertrophic pyloric stenosis with symptoms showing, for some unexplained reason, only at a later date cannot be decided from the evidence at hand. There are, in the literature, however, well-authenticated cases in which a thickening in the neighborhood of the cardia is found of sufficient degree so that even at postmortem examination the dilated esophagus filled with fluid will hold its contents, while the common type of dilatation of the esophagus empties itself readily.<sup>21</sup> Knight,<sup>22</sup> Case 3, described as an hypertrophy of the cardiac sphincter, is a typical example of this group. Consequently, it seems to us unquestionable that such constricting lesion of the lower esophagus or cardia occurs as the cause of a definite but small group of cases of dilatation of the esophagus without clinically discoverable cause. Spinal anesthesia will, of course, not relax such a lesion as was proven in our Case 4, and dilatation *per os* will probably prove to give only a relatively short period of relief of symptoms, as was also true in this case. The final diagnosis of this type will probably require identification by proving the presence of the fibromuscular ring.

4. *Dolicho-esophagus*: It is generally recognized by all who have clinical experience with idiopathic dilatation of the esophagus that the esophagus is usually also longer than normal. This is easily recognized in esophagoscopying such cases, and such a moderate increase in the length of the esophagus is not meant in the classification of the group of dolicho-esophagus. However, there is a group, a characteristic example of which is our Case 5, in which there is so extreme an increase in the length of the esophagus that the latter forms a compound curve and assumes an "S"-shape. Most observers have assumed that this extreme lengthening of the esophagus is due to the same cause as the lengthening previously mentioned as associated with practically all cases of idiopathic dilatation, namely, the hydrostatic pressure of the column of fluid in the dilated esophagus. Two facts make such an explanation highly improbable. In the first place, the form of the curve is "S"-shaped with one pocket at a much higher level than the other one. This is quite a constant finding and cannot be explained on the basis of hydrostatic pressure which would tend to produce the usual fusiform or pyriform shape

seen in the common example of achalasia. In the second place, the combination of such a lengthening of the esophagus associated with marked dilatation has been found in infancy.<sup>23</sup> It seems much more probable that this is an abnormality of the esophagus comparable to the dolichocolon, in which there is a congenital increase in length which is responsible for the compound curving of the structure and also causes an hydrostatic functional obstruction due to kinking of the lower end when the dilated and distorted esophagus is filled with fluid. We do not believe that this form of extreme lengthening of the esophagus in an "S"-shaped form is merely secondary to some disturbance in the emptying of the esophagus into the cardia, but we rather believe that it is the primary cause in these instances of the functional obstruction. An esophagoscope can be readily passed in these cases through the cardia, which is patent, into the stomach when it can be safely gotten down past the "S"-shaped curve of the esophagus. This was done in our case number five and the obstruction seems to be due merely to the functional condition present. In this type the dilated esophagus acts like a sac filled with fluid and obstructs the cardia by partially kinking the esophagus at the diaphragm. Another piece of evidence supporting this explanation for the dolicho-esophagus group is seen in the experience in such a case reported by Freeman<sup>24</sup> in 1923. Twenty years previously he had carried out an esophagoplasty in the neck which had shortened the esophagus. This procedure caused immediate relief of symptoms which continued for 20 years.

#### TREATMENT OF INTRACTABLE CASES

Everyone is agreed that the treatment for the majority of cases of idiopathic dilatation of the esophagus is relatively simple and effective. Dilatation of the esophagus produces in most cases a marked relief of symptoms, which occasionally is permanent but more often recurs after a variable interval. However, by repeated dilatations at regular or irregular intervals, the great majority of patients have sufficient relief, so that no more drastic method of attack is required. In a small group, however, such dilatation and all other conservative measures fail to produce any lasting improvement. The symptoms in such cases tend to become more severe and the problem of the patient's getting sufficient nourishment becomes a serious one. It is in this group of cases, intractable to dilatation and other conservative measures, that operative relief should be considered. Obviously, in the severe cases of true cardiospasm the focus of irritation should be removed. When this is accomplished, as in Case 1, the esophageal symptoms practically disappear, although some degree of dilatation of the esophagus is likely to remain for many years, as is the case in its counterpart, Hirschsprung's disease of the colon. When, however, the idiopathic dilatation of the esophagus is not due to a reflex irritation of the sympathetic innervation (as proven, for example, by spinal anesthesia) and relief is not obtained by dilatation and other conservative measures, then relief of the condition by operation is indicated if

the symptoms are sufficiently urgent or the course is progressively downward. Usually a tube can be gotten down into the stomach so that gastrostomy as a preparatory measure is not necessary.

An excellent review of the various operations undertaken in these resistant cases, with the results attained, is given by Ochsner and DeBakey.<sup>25</sup> There have, in general, been four different types of operation advocated for the relief of the esophageal stasis. Historically, the first operation is that devised by Mikulicz, in which the cardia of the stomach is mechanically dilated transgastrically at celiotomy. The rationale of this procedure was that manual dilatation produced a much greater degree of stretching of the cardia than can be produced instrumentally through the esophagus. Its disadvantages were two-fold: One, the danger of tearing the esophagus during the process of dilatation; and, secondly, the return of symptoms after the recovery by the cardia from the dilatation. It is still occasionally employed today, though it is usually regarded as inadequate.

A second type of operative attack is that advocated by Heller. In this procedure, the outer fibromuscular coats of the esophagus are divided longitudinally through the region of the cardia down to the submucosa. This is comparable to the very satisfactory operation employed to relieve congenital hypertrophic pyloric stenosis. Theoretically, this operation would be effective chiefly where there was an hypertrophic fibromuscular band, as for example in our third clinical group, but in the other types it would be relatively ineffective. As a matter of experience, it has been found that there is a high incidence of recurrence of symptoms after this operation.

A third operative approach, recently devised, was an effort to eliminate the sympathetic supply to the cardia. This attempt was based primarily upon experimental work in the laboratory, where it was found that the dilatation of the esophagus following section of the vagus nerves was prevented, if the sympathetic innervation of the cardia was interrupted. The results in the few cases in which this method of treatment has been used in the human, however, have been too unreliable to warrant its adoption.

The fourth operative procedure employed has been much more successful. Heyrovsky first proved the practicability of anastomosing the dilated esophagus and fundus of the stomach. His cases demonstrated that when this is undertaken below the diaphragm it is both a practical method of attack and is relatively safe. In the earlier attempts at making such an anastomosis, the stomach was carried through the diaphragm and the anastomosis was made intrathoracically. This was associated with a higher mortality rate than would probably result today. However, there seems to be no particular technical advantage to the supradiaphragmatic approach and the abdominal approach has had a low mortality rate. Continental surgeons have adopted esophagogastronomy in numerous instances and, in general, with excellent results. In America, however, it has not received the attention that it deserves. In spite of the excellent case reports of Lambert<sup>26</sup> in 1914, and Watts<sup>27</sup> in

1923. In addition to these two cases, gastrojejunostomy for idiopathic dilatation of the esophagus has been reported by American surgeons in sixteen other instances, Keller<sup>28</sup> adding one case, Churchill<sup>29</sup> two, Womack<sup>30</sup> two, Ochsner and DeBakey<sup>25</sup> two, Gray and Skinner<sup>31</sup> one, and Janes<sup>32</sup>, in the discussion of the last paper, added eight from the Toronto group operated

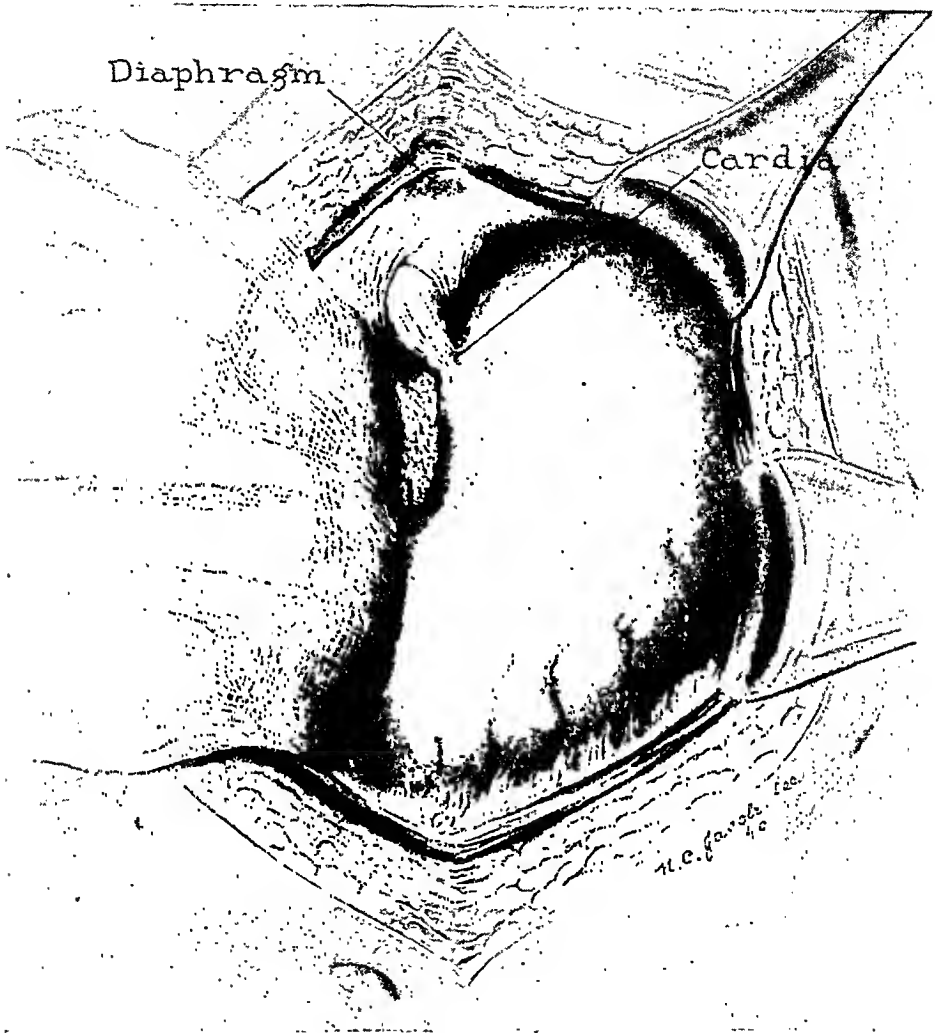


FIG. 11A

FIG. 11A.—Gastro-esophagostomy is carried out in Case 1. The cardia is exposed by complete mobilization of the left lobe of the liver.

upon by five different surgeons. We wish to add three cases of our own, making a total to date of 21 cases of gastro-esophagostomy reported by American surgeons for idiopathic dilatation of the esophagus.

#### OPERATIVE TECHNIC

The operation is a cardioplasty uniting the cardiac end of the stomach and the esophagus, similar to the Finney pyloroplasty (Fig. 11). The operative technic has already been well described in the American literature.<sup>33-35</sup>

The technic which we employed has been briefly published elsewhere.<sup>35</sup> We wish to call attention only to a few details: (1) The abdominal approach is superior for the ordinary case. (2) Adequate exposure is easily obtained by mobilization of the left lobe of the liver. In doing this, the left triangular ligament should be divided above the liver not only in its flat part but on each side as the two peritoneal surfaces start to separate in a "Y". This enables thorough mobilization of the left lobe of the liver. (3) A tape is passed around the cardia without injuring the veins. By traction on this

FIG. 11 (Cont'd)

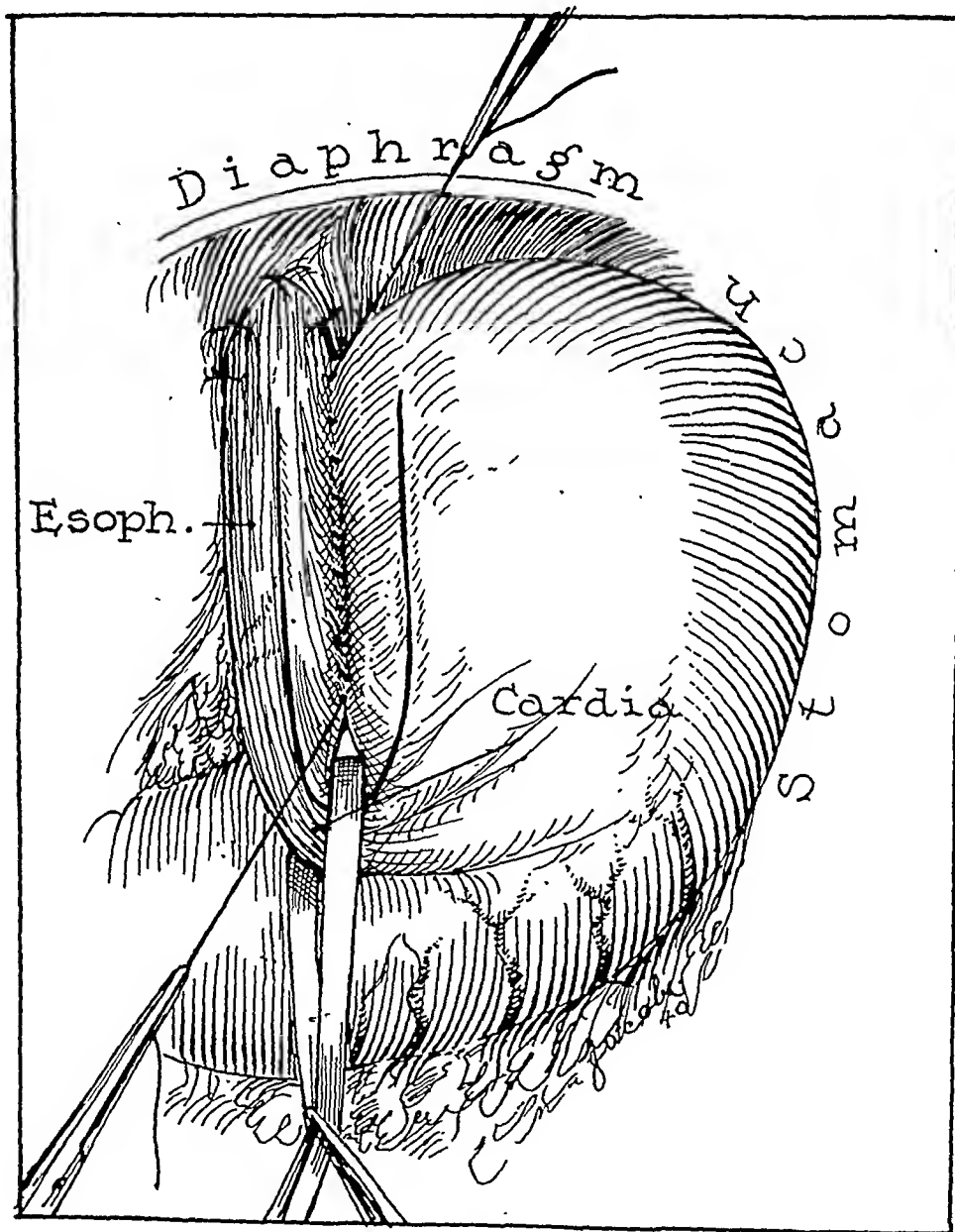


FIG. 11B

FIG. 11B.—After passing a tape about the cardia the peritoneum has been divided at the esophageal hiatus. The lower end of the esophagus is mobilized by blunt dissection and at least two inches of it pulled down into the abdomen. The crura of the diaphragm have been reattached to the esophagus at this higher level and the outer row of the posterior layer has been completed. The line of the incision is indicated by the "U."

tape, the peritoneal fold at the esophageal hiatus is easily made taut for division. After mobilization of the lower end of the thoracic esophagus by blunt dissection, two inches of the latter can easily be brought down into the abdomen. This traction is maintained throughout the first part of the

FIG. 11 (Cont'd)

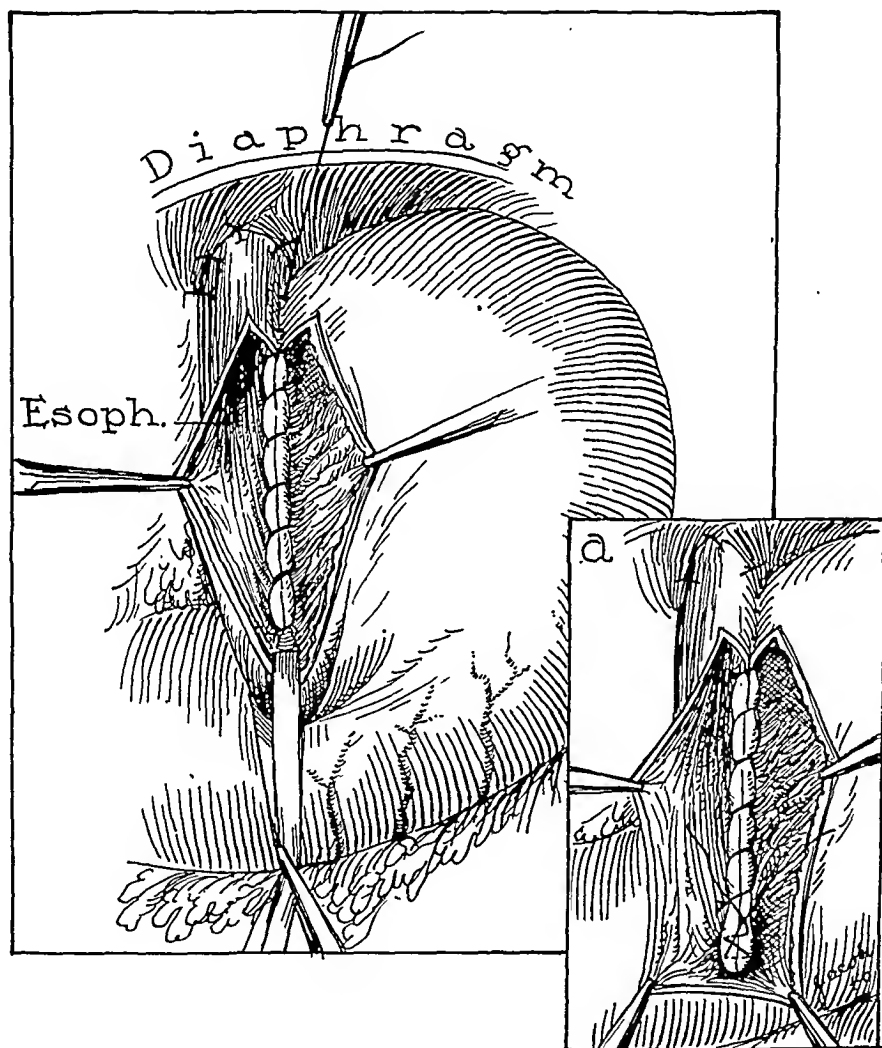


FIG. 11C

C. The stomach and esophagus have been opened except for the small bridge where the tape still maintains traction while the stomach and esophagus are sutured posteriorly. The tape and bridge at the cardia are now divided and one suture completes the outer posterior row.

anastomosis and in fact until the two rows of the posterior part of the anastomosis are completed except for the small bridge of tissue under the tape at the cardia. The tape is then removed, this bridge is divided and the posterior layer is completed with one figure-of-eight stitch. (4) It has not been necessary in our experience to tie off the esophagus with a tape, as advocated by Ochsner. The divided peritoneum is reattached to the esophagus at a higher level before the stomach and esophagus are opened and the parts

are well walled-off. The esophagus should be cleaned out carefully before operation but, even so, there may be some food residue in it which should be removed by suction. (5) After completion of the anastomosis it is not necessary to reattach the left lobe of the liver and in our cases drainage has not been necessary.

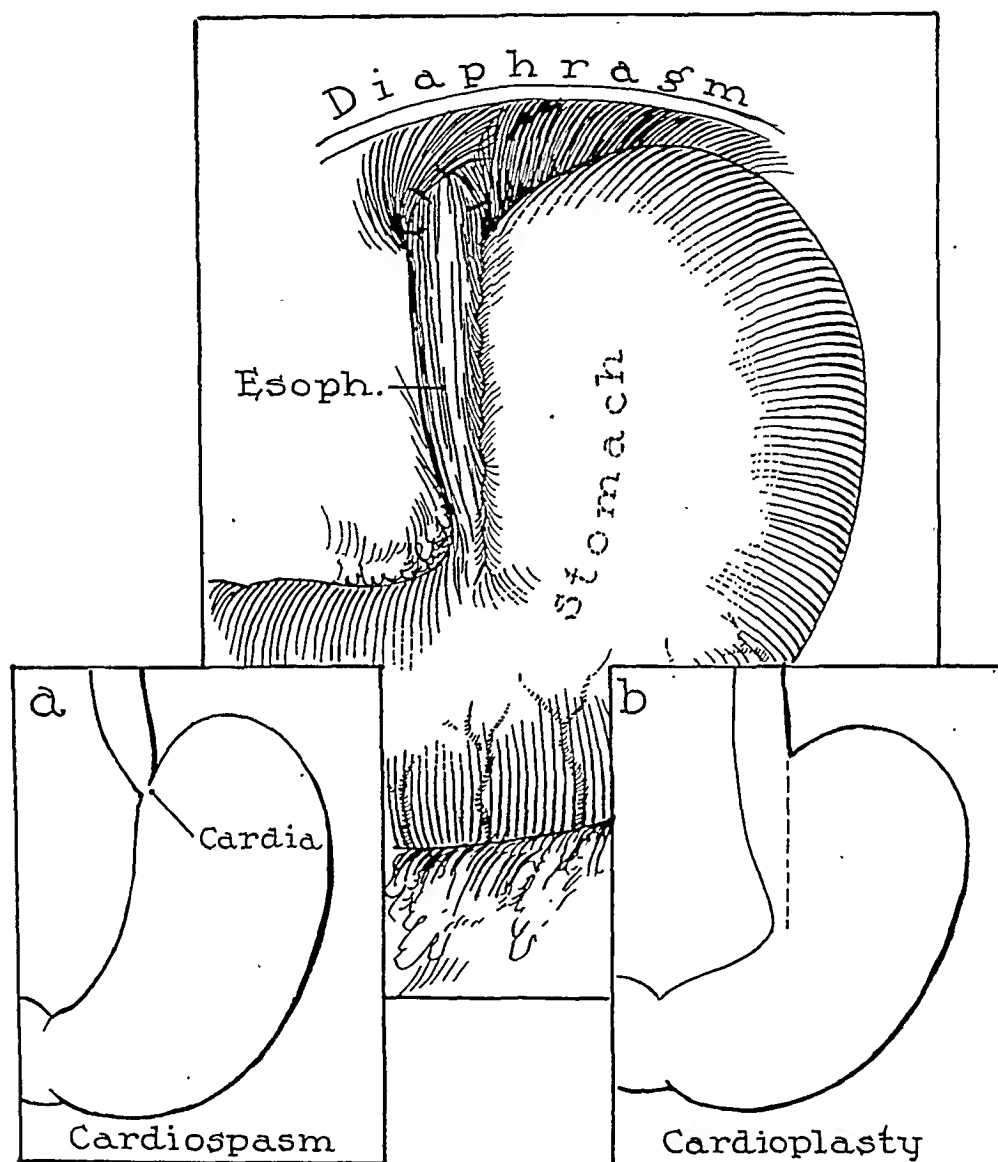


FIG. 11D

D. The two rows of the anterior segment have been completed making a wide opening between the esophagus and stomach.

#### RESULTS

Gastro-esophagostomy was carried out in this manner in three cases that failed to be relieved by repeated dilatations. In Case 4 a firm fibromuscular band was found at the pylorus. The pylorus itself when it was opened would not allow the passage of an ordinary lead pencil. Following operation the patient had a rapid convalescence. A Levine tube was left through the anastomosis for seven days. She was discharged from the hospital 19 days after operation eating a mixed diet. She rapidly gained 30 pounds in



weight, and is entirely relieved of her difficulty on eating, now six years after operation. Roentgenologic examination six months after operation showed that the dilatation of the esophagus had practically disappeared (Fig. 9). Repeated six years after operation, the cardia appeared normal. There was slight redundancy of the esophagus seen best in the supine position. In Case 5, the patient had a rapid convalescence. She left the hospital on the 23rd postoperative day, with marked improvement in her ability to eat but not complete cessation of symptoms, probably due to the fact that the operation had not affected the upper portion of the "S"-shaped curve. However, it has been found that the upper pocket can be emptied into the lower, and the patient gets relief from her symptoms if she lies on her side for 15 minutes after meals. She began eating a general mixed diet, which she was unable to do previously, and gradually gained weight. Six months after her operation she was having no trouble taking food if she did not eat too large an amount at a time. Now, six years after operation, she is quite a feeble old lady, being 84 years of age, but has had no major difficulty with her eating during this interval. It has not been possible to get a late follow-up of the roentgenographic appearance. Six months after operation the roentgenograms showed a definite improvement of the dilatation of the lower segment of the esophagus but little change in the upper pouch of the "S"-shaped curve, the latter would empty, however, on postural drainage. Barium entered the stomach much more quickly than before operation.

**Case 6.**—J. R., a 34-year-old French machine inspector, was admitted to the hospital, November 11, 1944, on account of difficulty in swallowing for the past three years. At first he was able to take solid foods if he washed them down with fluids. One and one-half months ago, he began having difficulty even getting liquids down. Diagnosis of cardiospasm was made on roentgenographic evidence in the Cleveland Clinic a year before admission. He had had seven dilatations during this year. At first he had improvement for several days following each dilatation, but for the last three or four times he had had very little improvement and the last time none at all. He has had vomiting spells every three weeks and frequently regurgitates his food. When he has the greatest difficulty in eating he develops a pain underneath the xyphoid accompanied by dyspnea and palpitation. He has lost 10 or 12 pounds during the present illness. Roentgenologic examination three months before admission showed a marked increase in the degree of dilatation and he was referred here as a candidate for operative treatment.

In the hospital it was found that the patient could not tolerate liquids at all well, regurgitating them every 10 to 15 minutes after ingestion. On physical examination the only finding of significance was the loss of weight. Roentgenologic examination on admission showed marked dilatation with some tortuosity of the lower half of the thoracic esophagus coming down to a smooth conical ending (Fig. 12). There were no definite peristaltic waves, though on deep inspiration, a variation in tone of the lower portion of the dilated esophagus could be seen.

*Esophagosopic Examination:* The esophagus showed marked dilatation. The lower part was filled with solid and semisolid food remnants. The stomach was entered easily with the esophagoscope. The cardia appeared normal. There was no evidence of stricture or malignancy.

Esophagogastrostomy (Finney pyloroplasty type) was performed on November 15.

1944. The operative findings showed no constriction at the cardia and no evidence of any other pathology in the abdomen. He had a normal convalescence following gastro-esophagostomy. No indwelling tube was put in at the time of operation. He was taking fluid well on the fourth day after operation, and was discharged from the hospital on the 15th postoperative day. Six months after operation he was having no trouble whatever in eating. He had gained 24 pounds in weight. On roentgenologic examination barium passed freely into the stomach though dilatation of the esophagus was still present but much less in extent than before operation. The cardia of the esophagus appeared of normal width, without the sharp conical shape noted before operation (Fig. 13).



FIG. 12

FIG. 12.—Case 6: Dilatation of the esophagus before operation.



FIG. 13

FIG. 13.—Case 6: Roentgenogram of the esophagus and cardia six months after operation shows disappearance of the sharp conical end of the esophagus. Dilatation of the esophagus is less but is still present. Cardia is of good width.

Thus, three cases of idiopathic dilatation of the esophagus, entirely resistant to the usual conservative treatment including repeated dilatations, have been relieved of all or the major part of their dysphagia by gastro-esophagostomy. Case 4 was an example of the group with a band constricting the cardia. Case 5 was an example of the dolicho-esophagus group with an "S"-shaped curve and pooling at two levels. Case 6 apparently was an example of the achalasia group which did not respond as most of this group do to esophageal dilatation. Operative relief of these patients is not unduly difficult nor too dangerous. The latter fact is attested to, I believe, by the successful result in Case 5 at the age of 78.

It is interesting that the relief of symptoms does not require the disappearance of the dilatation of the esophagus. In fact, the prompt return of the esophagus to a normal width, as occurred in Case 4, is somewhat

unusual. The other cases (Nos. 5 and 6) had a marked improvement in the emptying of the dilated esophagus into the stomach and some decrease in the dilatation. This is the usual experience as reported in the literature.

#### CONCLUSIONS

Dilatation of the esophagus without any clinically discoverable obstruction is not a disease entity but is a symptom-complex. At least four clinical types can be recognized, each with a different etiology: namely, (1) achalasia of the esophagus; (2) true cardiospasm; (3) partial constriction near the cardia; and (4) dolicho-esophagus.

Achalasia is probably the most common type. It usually responds well to dilatation. In true cardiospasm the reflex originating focus should be discovered and removed. Those cases caused by a partial constricting band near the cardia are few in number but are probably resistant to conservative treatment. Dolicho-esophagus, an "S"-shaped lengthening with pooling of esophageal contents at different levels, should probably be operated upon immediately on recognition. This type is very difficult to control when the dilatation becomes gigantic and is complicated by infection of the esophageal wall.

Subdiaphragmatic esophagogastronomy (of the Finney pyloroplasty type) appears to be the operation of choice in those cases of idiopathic dilatation of the esophagus that are resistant to the usual conservative measures. The symptomatic results of this operation are usually excellent whether or not the dilatation of the esophagus is entirely corrected. The danger of the operation is not excessive when proper precautions are taken. After this operation has been employed more extensively, the number of cases where it is indicated will probably be considerably increased but it should never replace conservative dilatation in the majority of cases.

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The major portion of the barium mixture given was still in the esophagus at the end of six hours. Esophagoscopy showed marked retention of cloudy fluid and food particles with a typically pasty-looking mucous membrane at the level of the diaphragm. The mucous membrane folds lie in apposition to each other but offer no resistance to the passage of the esophagoscope through the cardia. Three dilatations of the cardia gave little or no relief. In spite of this treatment combined with other conservative measures, such as esophageal lavage, atropine, *etc.*, it was impossible to get sufficient nourishment for her. A satisfactory spinal anesthesia was given (complete to the level of T-7) without marked benefit either to the patient's ability to swallow or to the dilatation of the esophagus. Possibly barium got through from the lower pouch into the stomach slightly more easily.

COMMENT: In Cases 4 and 5, then, satisfactory spinal anesthesia produced no striking change in two typical examples of idiopathic dilatation of the esophagus. These, therefore, fall into our Group B, in which sympathetic overactivity apparently plays no rôle in the production of the syndrome, while Cases 1, 2, and 3 fall into Group A, where the esophageal abnormality is apparently on the basis of sympathetic overactivity. Unfortunately, we have not yet had an opportunity to examine the reaction to spinal anesthesia in simple cases of idiopathic dilatation of the esophagus which respond readily to dilatation.

#### CLINICAL TYPES

From an analysis of our series of 85 cases of idiopathic dilatation of the esophagus (usually diagnosed as achalasia of the cardia or as cardiospasm), and aided by the information obtained from the use of spinal anesthesia as a tool of investigation, we feel that it is now possible to recognize four different clinical types which probably also differ from each other in their etiology. These types are: (1) Achalasia of the esophagus; (2) true cardiospasm; (3) dilatation associated with a constriction at, or just above, the cardia; and (4) dolicho-esophagus. Let us investigate separately each of these clinical groups.

1. *Achalasia of the esophagus* is probably the most common variety encountered. It usually readily responds to dilatation of the esophagus and is due to an incoördination of the neuromuscular apparatus at the lower end of the esophagus, whereby the cardia fails to relax properly. At present, there are no pathognomonic criteria clinically of such a failure of relaxation and, consequently, the diagnosis of this type must be made largely by exclusion of the other three types, though probably most of the cases of idiopathic dilatation of the esophagus that respond promptly to simple dilatation and whose symptoms are readily controlled by this method fall in this category.

2. *True Cardiospasm*: The roentgenographic appearance in this clinical type appears identical to that seen in achalasia. However, in this clinical syndrome, a reflex focus of irritation can be found, the eradication of which will largely or completely remove the difficulty in the passage of food from the esophagus into the stomach. Such cases respond to spinal anesthesia with temporary relief. During the anesthesia, the free passage of barium

into the stomach can be seen under the fluoroscope. Probably the most frequent foci for the origin of the reflex causing the cardiospasm are ulcer of the stomach or duodenum, other irritated lesions involving the posterior peritoneum, and cholelithiasis.

3. *Dilatation Associated with Constriction at the Cardia*: This group probably represents a small percentage of the cases of idiopathic dilatation of the esophagus. Our fourth case, however, seems to be definitely a member of this group. At operation, a circular fibromuscular band was found around the region of the cardia and the lumen of the latter would not admit a lead pencil. There was no evidence of any recent acute inflammatory reaction associated with this fibrosis. Whether this was fibrositis due to peri-esophagitis as Mosier hypothecates or whether a congenital abnormality somewhat like hypertrophic pyloric stenosis with symptoms showing, for some unexplained reason, only at a later date cannot be decided from the evidence at hand. There are, in the literature, however, well-authenticated cases in which a thickening in the neighborhood of the cardia is found of sufficient degree so that even at postmortem examination the dilated esophagus filled with fluid will hold its contents, while the common type of dilatation of the esophagus empties itself readily.<sup>21</sup> Knight,<sup>22</sup> Case 3, described as an hypertrophy of the cardiac sphincter, is a typical example of this group. Consequently, it seems to us unquestionable that such constricting lesion of the lower esophagus or cardia occurs as the cause of a definite but small group of cases of dilatation of the esophagus without clinically discoverable cause. Spinal anesthesia will, of course, not relax such a lesion as was proven in our Case 4, and dilatation *per os* will probably prove to give only a relatively short period of relief of symptoms, as was also true in this case. The final diagnosis of this type will probably require identification by proving the presence of the fibromuscular ring.

4. *Dolicho-esophagus*: It is generally recognized by all who have clinical experience with idiopathic dilatation of the esophagus that the esophagus is usually also longer than normal. This is easily recognized in esophagoscopy such cases, and such a moderate increase in the length of the esophagus is not meant in the classification of the group of dolicho-esophagus. However, there is a group, a characteristic example of which is our Case 5, in which there is so extreme an increase in the length of the esophagus that the latter forms a compound curve and assumes an "S"-shape. Most observers have assumed that this extreme lengthening of the esophagus is due to the same cause as the lengthening previously mentioned as associated with practically all cases of idiopathic dilatation, namely, the hydrostatic pressure of the column of fluid in the dilated esophagus. Two facts make such an explanation highly improbable. In the first place, the form of the curve is "S"-shaped with one pocket at a much higher level than the other one. This is quite a constant finding and cannot be explained on the basis of hydrostatic pressure which would tend to produce the usual fusiform or pyriform shape

seen in the common example of achalasia. In the second place, the combination of such a lengthening of the esophagus associated with marked dilatation has been found in infancy.<sup>23</sup> It seems much more probable that this is an abnormality of the esophagus comparable to the dolichocolon, in which there is a congenital increase in length which is responsible for the compound curving of the structure and also causes an hydrostatic functional obstruction due to kinking of the lower end when the dilated and distorted esophagus is filled with fluid. We do not believe that this form of extreme lengthening of the esophagus in an "S"-shaped form is merely secondary to some disturbance in the emptying of the esophagus into the cardia, but we rather believe that it is the primary cause in these instances of the functional obstruction. An esophagoscope can be readily passed in these cases through the cardia, which is patent, into the stomach when it can be safely gotten down past the "S"-shaped curve of the esophagus. This was done in our case number five and the obstruction seems to be due merely to the functional condition present. In this type the dilated esophagus acts like a sac filled with fluid and obstructs the cardia by partially kinking the esophagus at the diaphragm. Another piece of evidence supporting this explanation for the dolicho-esophagus group is seen in the experience in such a case reported by Freeman<sup>24</sup> in 1923. Twenty years previously he had carried out an esophagoplasty in the neck which had shortened the esophagus. This procedure caused immediate relief of symptoms which continued for 20 years.

#### TREATMENT OF INTRACTABLE CASES

Everyone is agreed that the treatment for the majority of cases of idiopathic dilatation of the esophagus is relatively simple and effective. Dilatation of the esophagus produces in most cases a marked relief of symptoms, which occasionally is permanent but more often recurs after a variable interval. However, by repeated dilatations at regular or irregular intervals, the great majority of patients have sufficient relief, so that no more drastic method of attack is required. In a small group, however, such dilatation and all other conservative measures fail to produce any lasting improvement. The symptoms in such cases tend to become more severe and the problem of the patient's getting sufficient nourishment becomes a serious one. It is in this group of cases, intractable to dilatation and other conservative measures, that operative relief should be considered. Obviously, in the severe cases of true cardiospasm the focus of irritation should be removed. When this is accomplished, as in Case 1, the esophageal symptoms practically disappear, although some degree of dilatation of the esophagus is likely to remain for many years, as is the case in its counterpart, Hirschsprung's disease of the colon. When, however, the idiopathic dilatation of the esophagus is not due to a reflex irritation of the sympathetic innervation (as proven, for example, by spinal anesthesia) and relief is not obtained by dilatation and other conservative measures, then relief of the condition by operation is indicated if

the symptoms are sufficiently urgent or the course is progressively downward. Usually a tube can be gotten down into the stomach so that gastrostomy as a preparatory measure is not necessary.

An excellent review of the various operations undertaken in these resistant cases, with the results attained, is given by Ochsner and DeBakey.<sup>25</sup> There have, in general, been four different types of operation advocated for the relief of the esophageal stasis. Historically, the first operation is that devised by Mikulicz, in which the cardia of the stomach is mechanically dilated transgastrically at celiotomy. The rationale of this procedure was that manual dilatation produced a much greater degree of stretching of the cardia than can be produced instrumentally through the esophagus. Its disadvantages were two-fold: One, the danger of tearing the esophagus during the process of dilatation; and, secondly, the return of symptoms after the recovery by the cardia from the dilatation. It is still occasionally employed today, though it is usually regarded as inadequate.

A second type of operative attack is that advocated by Heller. In this procedure, the outer fibromuscular coats of the esophagus are divided longitudinally through the region of the cardia down to the submucosa. This is comparable to the very satisfactory operation employed to relieve congenital hypertrophic pyloric stenosis. Theoretically, this operation would be effective chiefly where there was an hypertrophic fibromuscular band, as for example in our third clinical group, but in the other types it would be relatively ineffective. As a matter of experience, it has been found that there is a high incidence of recurrence of symptoms after this operation.

A third operative approach, recently devised, was an effort to eliminate the sympathetic supply to the cardia. This attempt was based primarily upon experimental work in the laboratory, where it was found that the dilatation of the esophagus following section of the vagus nerves was prevented, if the sympathetic innervation of the cardia was interrupted. The results in the few cases in which this method of treatment has been used in the human, however, have been too unreliable to warrant its adoption.

The fourth operative procedure employed has been much more successful. Heyrovsky first proved the practicability of anastomosing the dilated esophagus and fundus of the stomach. His cases demonstrated that when this is undertaken below the diaphragm it is both a practical method of attack and is relatively safe. In the earlier attempts at making such an anastomosis, the stomach was carried through the diaphragm and the anastomosis was made intrathoracically. This was associated with a higher mortality rate than would probably result today. However, there seems to be no particular technical advantage to the supradiaphragmatic approach and the abdominal approach has had a low mortality rate. Continental surgeons have adopted esophagogastronomy in numerous instances and, in general, with excellent results. In America, however, it has not received the attention that it deserves. In spite of the excellent case reports of Lambert<sup>26</sup> in 1914, and Watts<sup>27</sup> in



1923. In addition to these two cases, gastrojejunostomy for idiopathic dilatation of the esophagus has been reported by American surgeons in sixteen other instances, Keller<sup>28</sup> adding one case, Churchill<sup>29</sup> two, Womack<sup>30</sup> two, Ochsner and DeBakey<sup>25</sup> two, Gray and Skinner<sup>31</sup> one, and Janes<sup>32</sup>, in the discussion of the last paper, added eight from the Toronto group operated

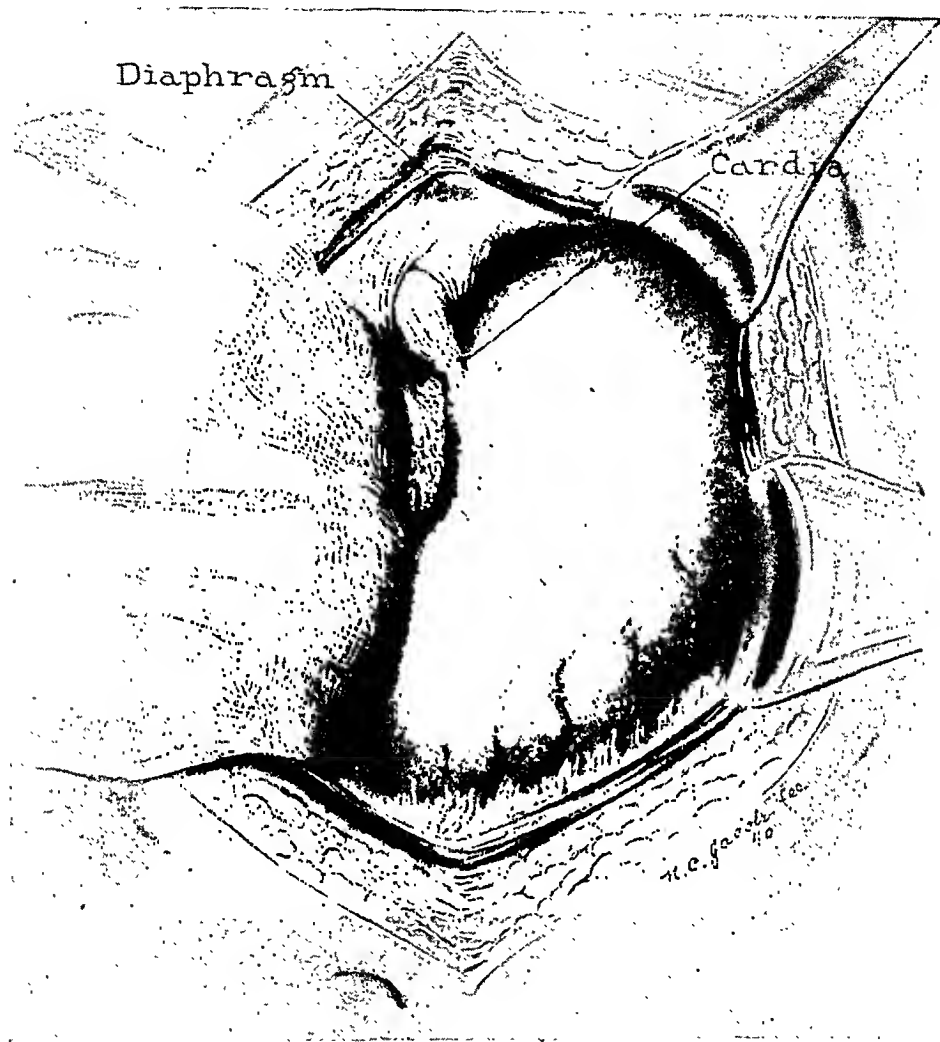


FIG. 11A

FIG. 11A.—Gastro-esophagostomy is carried out in Case 1. The cardia is exposed by complete mobilization of the left lobe of the liver.

upon by five different surgeons. We wish to add three cases of our own, making a total to date of 21 cases of gastro-esophagostomy reported by American surgeons for idiopathic dilatation of the esophagus.

#### OPERATIVE TECHNIC

The operation is a cardioplasty uniting the cardiac end of the stomach and the esophagus, similar to the Finney pyloroplasty (Fig. 11). The operative technic has already been well described in the American literature.<sup>33-35</sup>

The technic which we employed has been briefly published elsewhere.<sup>35</sup> We wish to call attention only to a few details: (1) The abdominal approach is superior for the ordinary case. (2) Adequate exposure is easily obtained by mobilization of the left lobe of the liver. In doing this, the left triangular ligament should be divided above the liver not only in its flat part but on each side as the two peritoneal surfaces start to separate in a "Y". This enables thorough mobilization of the left lobe of the liver. (3) A tape is passed around the cardia without injuring the veins. By traction on this

FIG. 11 (Cont'd)

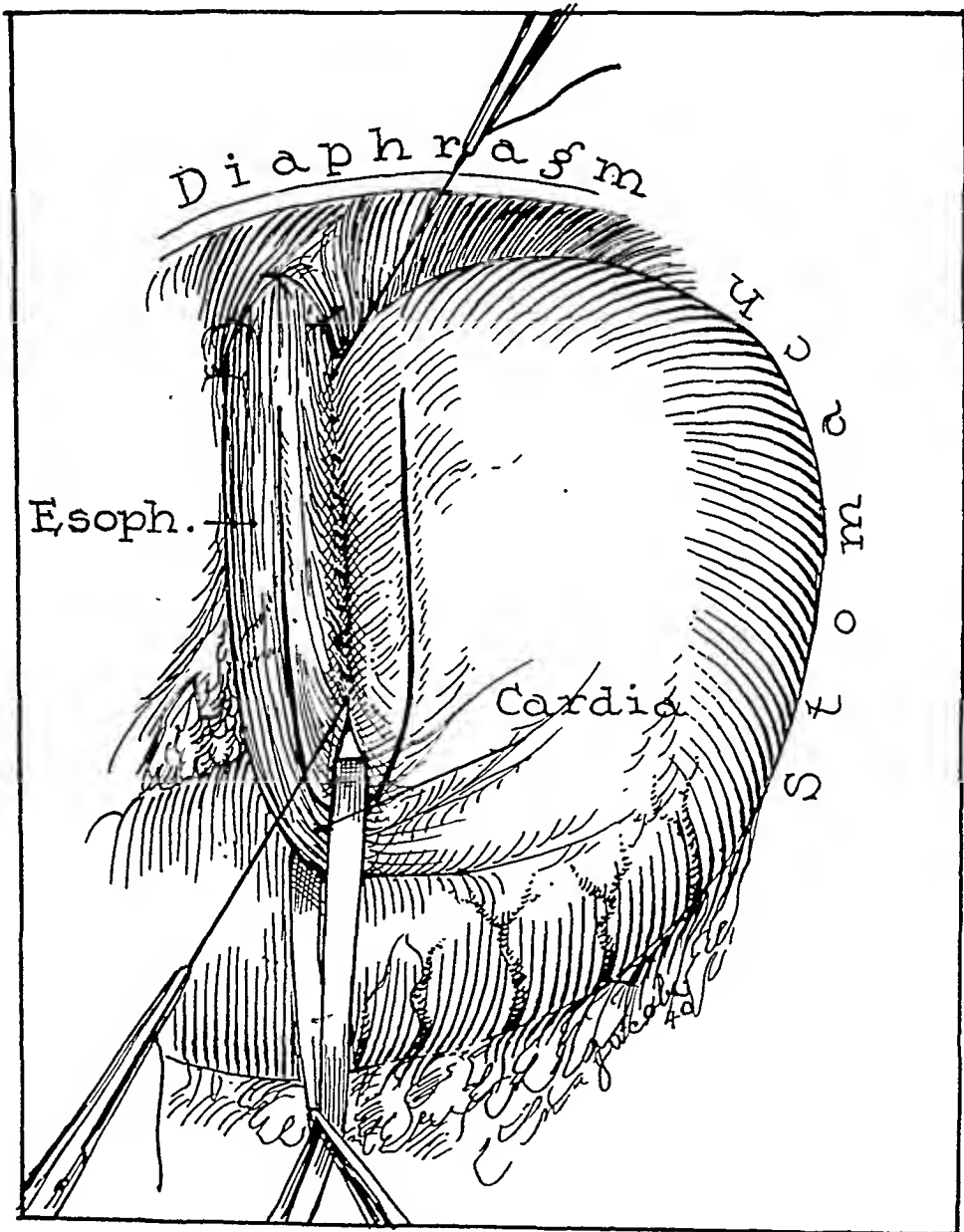


FIG. 11B

FIG. 11B.—After passing a tape about the cardia the peritoneum has been divided at the esophageal hiatus. The lower end of the esophagus is mobilized by blunt dissection and at least two inches of it pulled down into the abdomen. The crura of the diaphragm have been reattached to the esophagus at this higher level and the outer row of the posterior layer has been completed. The line of the incision is indicated by the "U."

tape, the peritoneal fold at the esophageal hiatus is easily made taut for division. After mobilization of the lower end of the thoracic esophagus by blunt dissection, two inches of the latter can easily be brought down into the abdomen. This traction is maintained throughout the first part of the

FIG. 11 (Cont'd)

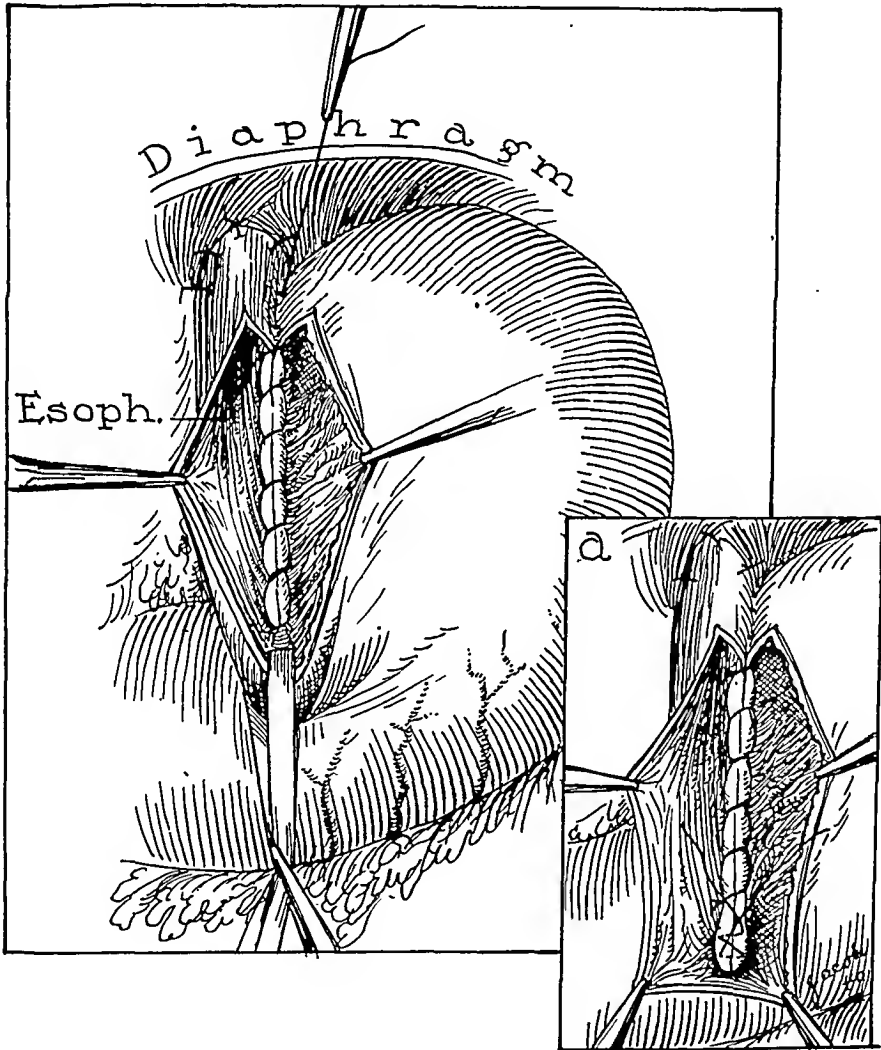


FIG. 11C

C. The stomach and esophagus have been opened except for the small bridge where the tape still maintains traction while the stomach and esophagus are sutured posteriorly. The tape and bridge at the cardia are now divided and one suture completes the outer posterior row.

anastomosis and in fact until the two rows of the posterior part of the anastomosis are completed except for the small bridge of tissue under the tape at the cardia. The tape is then removed, this bridge is divided and the posterior layer is completed with one figure-of-eight stitch. (4) It has not been necessary in our experience to tie off the esophagus with a tape, as advocated by Ochsner. The divided peritoneum is reattached to the esophagus at a higher level before the stomach and esophagus are opened and the parts

are well walled-off. The esophagus should be cleaned out carefully before operation but, even so, there may be some food residue in it which should be removed by suction. (5) After completion of the anastomosis it is not necessary to reattach the left lobe of the liver and in our cases drainage has not been necessary.

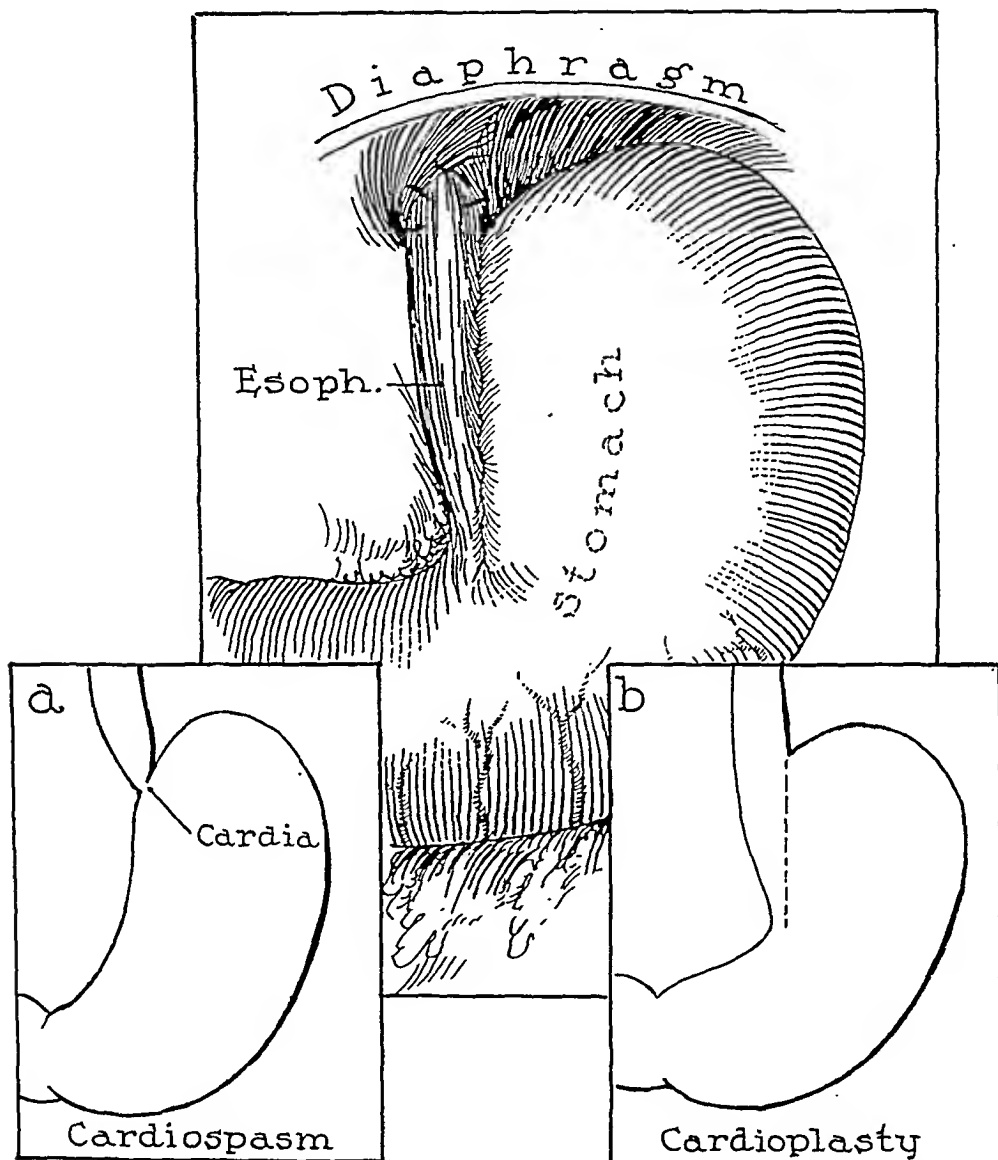


FIG. 11D

D. The two rows of the anterior segment have been completed making a wide opening between the esophagus and stomach.

#### RESULTS

Gastro-esophagostomy was carried out in this manner in three cases that failed to be relieved by repeated dilatations. In Case 4 a firm fibromuscular band was found at the pylorus. The pylorus itself when it was opened would not allow the passage of an ordinary lead pencil. Following operation the patient had a rapid convalescence. A Levine tube was left through the anastomosis for seven days. She was discharged from the hospital 19 days after operation eating a mixed diet. She rapidly gained 30 pounds in

weight, and is entirely relieved of her difficulty on eating, now six years after operation. Roentgenologic examination six months after operation showed that the dilatation of the esophagus had practically disappeared (Fig. 9). Repeated six years after operation, the cardia appeared normal. There was slight redundancy of the esophagus seen best in the supine position. In Case 5, the patient had a rapid convalescence. She left the hospital on the 23rd postoperative day, with marked improvement in her ability to eat but not complete cessation of symptoms, probably due to the fact that the operation had not affected the upper portion of the "S"-shaped curve. However, it has been found that the upper pocket can be emptied into the lower, and the patient gets relief from her symptoms if she lies on her side for 15 minutes after meals. She began eating a general mixed diet, which she was unable to do previously, and gradually gained weight. Six months after her operation she was having no trouble taking food if she did not eat too large an amount at a time. Now, six years after operation, she is quite a feeble old lady, being 84 years of age, but has had no major difficulty with her eating during this interval. It has not been possible to get a late follow-up of the roentgenographic appearance. Six months after operation the roentgenograms showed a definite improvement of the dilatation of the lower segment of the esophagus but little change in the upper pouch of the "S"-shaped curve, the latter would empty, however, on postural drainage. Barium entered the stomach much more quickly than before operation.

**Case 6.**—J. R., a 34-year-old French machine inspector, was admitted to the hospital, November 11, 1944, on account of difficulty in swallowing for the past three years. At first he was able to take solid foods if he washed them down with fluids. One and one-half months ago, he began having difficulty even getting liquids down. Diagnosis of cardiospasm was made on roentgenographic evidence in the Cleveland Clinic a year before admission. He had had seven dilatations during this year. At first he had improvement for several days following each dilatation, but for the last three or four times he had had very little improvement and the last time none at all. He has had vomiting spells every three weeks and frequently regurgitates his food. When he has the greatest difficulty in eating he develops a pain underneath the xyphoid accompanied by dyspnea and palpitation. He has lost 10 or 12 pounds during the present illness. Roentgenologic examination three months before admission showed a marked increase in the degree of dilatation and he was referred here as a candidate for operative treatment.

In the hospital it was found that the patient could not tolerate liquids at all well, regurgitating them every 10 to 15 minutes after ingestion. On physical examination the only finding of significance was the loss of weight. Roentgenologic examination on admission showed marked dilatation with some tortuosity of the lower half of the thoracic esophagus coming down to a smooth conical ending (Fig. 12). There were no definite peristaltic waves, though on deep inspiration, a variation in tone of the lower portion of the dilated esophagus could be seen.

*Esophagoscopy Examination:* The esophagus showed marked dilatation. The lower part was filled with solid and semisolid food remnants. The stomach was entered easily with the esophagoscope. The cardia appeared normal. There was no evidence of stricture or malignancy.

Esophagogastrostomy (Finney pyloroplasty type) was performed on November 15,

1944. The operative findings showed no constriction at the cardia and no evidence of any other pathology in the abdomen. He had a normal convalescence following gastro-esophagostomy. No indwelling tube was put in at the time of operation. He was taking fluid well on the fourth day after operation, and was discharged from the hospital on the 15th postoperative day. Six months after operation he was having no trouble whatever in eating. He had gained 24 pounds in weight. On roentgenologic examination barium passed freely into the stomach though dilatation of the esophagus was still present but much less in extent than before operation. The cardia of the esophagus appeared of normal width, without the sharp conical shape noted before operation (Fig. 13).



FIG. 12

FIG. 12.—Case 6: Dilatation of the esophagus before operation.



FIG. 13

FIG. 13.—Case 6: Roentgenogram of the esophagus and cardia six months after operation shows disappearance of the sharp conical end of the esophagus. Dilatation of the esophagus is less but is still present. Cardia is of good width.

Thus, three cases of idiopathic dilatation of the esophagus, entirely resistant to the usual conservative treatment including repeated dilatations, have been relieved of all or the major part of their dysphagia by gastro-esophagostomy. Case 4 was an example of the group with a band constricting the cardia. Case 5 was an example of the dolicho-esophagus group with an "S"-shaped curve and pooling at two levels. Case 6 apparently was an example of the achalasia group which did not respond as most of this group do to esophageal dilatation. Operative relief of these patients is not unduly difficult nor too dangerous. The latter fact is attested to, I believe, by the successful result in Case 5 at the age of 78.

It is interesting that the relief of symptoms does not require the disappearance of the dilatation of the esophagus. In fact, the prompt return of the esophagus to a normal width, as occurred in Case 4, is somewhat

unusual. The other cases (Nos. 5 and 6) had a marked improvement in the emptying of the dilated esophagus into the stomach and some decrease in the dilatation. This is the usual experience as reported in the literature.

#### CONCLUSIONS

Dilatation of the esophagus without any clinically discoverable obstruction is not a disease entity but is a symptom-complex. At least four clinical types can be recognized, each with a different etiology: namely, (1) achalasia of the esophagus; (2) true cardiospasm; (3) partial constriction near the cardia; and (4) dolicho-esophagus.

Achalasia is probably the most common type. It usually responds well to dilatation. In true cardiospasm the reflex originating focus should be discovered and removed. Those cases caused by a partial constricting band near the cardia are few in number but are probably resistant to conservative treatment. Dolicho-esophagus, an "S"-shaped lengthening with pooling of esophageal contents at different levels, should probably be operated upon immediately on recognition. This type is very difficult to control when the dilatation becomes gigantic and is complicated by infection of the esophageal wall.

Subdiaphragmatic esophagogastrostomy (of the Finney pyloroplasty type) appears to be the operation of choice in those cases of idiopathic dilatation of the esophagus that are resistant to the usual conservative measures. The symptomatic results of this operation are usually excellent whether or not the dilatation of the esophagus is entirely corrected. The danger of the operation is not excessive when proper precautions are taken. After this operation has been employed more extensively, the number of cases where it is indicated will probably be considerably increased but it should never replace conservative dilatation in the majority of cases.

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# CONGENITAL OR HEREDITARY POLYPOSIS OF THE COLON\*

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IN RECENT YEARS our interest in the subject of multiple polyposis of the colon has been greatly aroused due to the fact that five patients with this disease have come under our care. There was, unquestionably, an hereditary tendency in four of these cases, and no history of an hereditary background in the fifth. We are particularly interested in the congenital or hereditary type of this disease, and the greater portion of this paper will be devoted to that phase of the condition. An hereditary tendency has been reported in 50 per cent of the cases of multiple polyposis of the colon, but we believe that if sufficient and accurate information could be secured from the family in question, the hereditary tendency would be much greater. This does not apply to cases of solitary polypi or a few scattered polypi in the colon or rectum.

Diffuse polyposis of the colon has been recognized as a disease entity for many years. Menzel, according to Warwick,<sup>2</sup> first called attention to this fact in 1721. Lushka,<sup>3</sup> in 1861, reported a case in which there were thousands of polypi in the colon of a woman, age 30. As Mayo and Wakefield<sup>4</sup> state, this is the most convincing report of the disease by an early writer. Harrison Cripps,<sup>5</sup> in 1882, was the first to record that polyposis of the colon occurred in several members of one family.

## CLASSIFICATION

The classification of this disease leaves much to be desired. However, the two classifications that are most widely accepted are those of Erdmann and Morris,<sup>6</sup> and Wesson and Bargaen.<sup>7</sup> Erdmann and Morris divide polypi of the colon into two groups: (1) Those which are adolescent, or congenital; and (2) those which are adult, or acquired. Wesson and Bargaen divide polypi into (1) true polypi; and (2) postinflammatory polypi. Fitzgibbon and Rankin<sup>8</sup> classify polypi on the basis of their gross characteristics and histologic nature. These classifications make it emphatic that there are two types of polypi in the colon.

## ETIOLOGY

The congenital or hereditary type of multiple polyposis of the colon is a definite clinical entity. The disease may be present in both males and females, more commonly in the male, and it may be transmitted by both sexes. Instances of multiple polyposis in more than one member of a family have been reported by numerous writers.<sup>4, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17</sup> No patient has been known to be born with this disease. McKenney<sup>10</sup> reported a case of a boy, age 2, who had this disease, this being the youngest case on record. Evi-

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\* This paper was to have been presented before the Annual Meeting of the American Surgical Association, May, 1945.

dently, individuals are not born with this disease, but develop it later in life. None of our cases developed symptoms before the age of 14. Lockhart-Mummery<sup>9</sup> stated that he sigmoidoscoped a man, age 39, because he came from a family with this disease. The colon was normal, but four years later marked polyposis was present. The disease does not have to appear in early infancy or childhood to prove the question of heredity. Certain dominant characteristics do not manifest themselves until after puberty, or even middle age.

The most logical explanation of the hereditary aspect of this disease is that there occurs a mutation of the genes in an individual who has not exhibited the disease, and he passes the mutated genes on to his children. The genes may be passed as a dominant or recessive characteristic. The disease will occur in every generation if the genes is dominant; if it is recessive, both parents must carry the mutated genes before the condition will be seen. Lockhart-Mummery,<sup>9</sup> who expounded this theory, surmised that in multiple polyposis the genes is a mendelian dominant. Bernstein's<sup>16</sup> cases show that the disease may appear in one generation, skip the second, only to reappear in the third.

When the disease is found in an individual, all members of the family should be examined thoroughly for the presence of polypi. Several cases have been reported in recent years when the initial history failed to show the presence of the disease in other members of the family, but subsequent questioning revealed the disease in other close relatives.

Most writers agree that acquired multiple polyposis of the colon is secondary to irritation or infection, and that chronic ulcerative colitis is the disease which most commonly causes polypi of the colon to secondarily develop. Rankin<sup>18</sup> reported diffuse polyposis of the colon in 69 of 693 cases of chronic ulcerative colitis. Barger and Coffey<sup>15</sup> reported a series of 417 patients with chronic ulcerative colitis. Fifteen point eight per cent of this group developed polypi of the colon, and 16.6 per cent of this group had disseminated polyposis.

#### PATHOLOGY

In polyposis, the polypi vary in size from 1 mm. to 1-2 cm. in diameter. They may be pedunculated or sessile, the pedunculated polypus having a pedicle or stalk. In congenital multiple polyposis, the polypi are distributed throughout the colon. The specimen removed from one of our patients is shown in Figure 1. In our cases, the sessile type has predominated. All of the polypi are first sessile in nature, and many of these become pedunculated. The acquired polypi are more irregular in size and shape, more scattered, and fewer in number than the congenital polypi.

#### RELATION OF THE POLYPI TO MALIGNANCY.

Friedell and Wakefield<sup>1</sup> state that all polypi of the colon probably will become malignant if the patient who has them lives long enough. Many

writers agree with this statement. Barga and Coffey<sup>15</sup> found that carcinoma is much more likely to develop in congenital multiple polyposis than in the acquired form, the relationship being 82.8 per cent to 21.9 per cent in their two series of cases.

Proof of the tendency of the polypi to become malignant is shown by the reports of many writers. In a series of 19 cases of congenital multiple polyposis reported by Mayo and Wakefield,<sup>4</sup> six developed carcinoma. McKenney<sup>10</sup> reported carcinomatous change in 33.3 per cent of his cases. In 1928, Hullsiek<sup>14</sup> reported that of 128 cases of multiple polyposis of the colon in the literature, 46 developed carcinoma. Numerous other writers have reported cases of polyposis with malignant changes.<sup>6, 11, 12, 13, 16, 19, 20, 21, 22</sup>

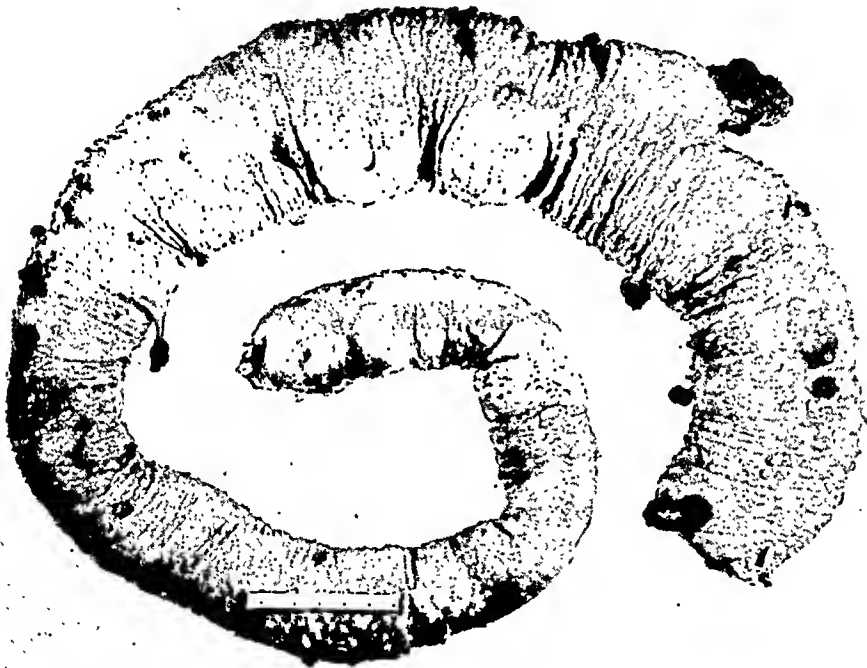


FIG. 1.—Specimen of large intestine removed from Patient No. 1 at operation. The mucosa is diffusely covered with countless wart-like nodules which vary in size from pin point to  $1 \times 2.5$  cm., many of them confluent. Their elevation above the plane of the mucosa varies from a fraction of 1 mm. to 3 or 4 mm.

They are greyish-red in color and fairly firm in consistency. The mucosa between the wart-like elevations is not thickened, but pale, smooth, and glistening. There are also numerous sessile and pedunculated polypi, representing apparently increase in size of the wart-like growths.

The polypi project above the plane of the mucosa from 5 to 4 cm. and their cross section area varies from  $2 \times 4$  mm. to  $2.6 \times 3.2$  cm. The large polypi are dendritic in character, dusky purplish-red in color, and firm in consistency.

Numerous sections were taken from the growth with an idea of showing the evolution of the polypi.

Cattell<sup>23</sup> quoted Ewing as saying that "nowhere else can the change from normal mucosa to inflammation, gland cell hypertrophy, adenoma, and adenocarcinoma, be so clearly demonstrated as in multiple polyposis of the colon." These changes are well illustrated in Figures 2-6 which are sections of polypi removed from one of our patients. (E.H.)

We have found that the larger polypi have a greater tendency toward malignancy. Malignant change is suggested by ulceration, nodular irregularities, and a broad pedicle and base. Grossly, firmness, induration, and fixation are suggestive of malignancy.

In addition to the polyposis, two of our cases showed large carcinomatous masses present in the colon, one of which was producing partial obstruction.

#### SYMPTOMS

The early symptoms in this disease are very mild, and, therefore, the patient is not likely to present himself for examination and treatment until the symptoms have been present for many years. Two of our patients had symptoms for seven years before consulting a physician. Because of the mildness of the early symptoms, some of the polypi may have undergone malignant changes before medical consultation is sought, as mentioned above. One of our cases had a carcinoma of the stomach and another an obstructing lesion of the rectosigmoid before seeing a physician. Both had practically no symptoms due to the colonic polypi.

As Slaughter<sup>24</sup> stated, polypi can produce any of the reactions of colonic or rectal irritation. Rectal bleeding and diarrhea are probably the two most common complaints. The bleeding may be mild or severe in character. One of our patients had a massive hemorrhage before consulting a physician. Bargen and Coffey<sup>15</sup> obtained a history of rectal bleeding in 62 per cent of 29 cases. Frequent loose stools may be the only symptom in some cases. Four of our five cases complained of mucus in the stools. Intermittent attacks of crampy, abdominal pain are common. Other more vague complaints that may be present are nausea, indigestion, easy fatigue, loss of weight, and loss of appetite.

A summary of the complaints in our five patients is shown in Table I.

TABLE I  
SYMPTOMS IN FIVE CASES OF MULTIPLE POLYPOSIS

Complaint	No. of Cases
Abdominal cramps .....	4
Mucus in stools.....	4
Blood in stools.....	3
Diarrhea.....	3
Weight loss.....	3
Nausea.....	2
Loss of appetite.....	2
Indigestion.....	2
Easy fatigue.....	2
Vomiting.....	2

#### DIAGNOSIS

Complete examination of the rectum and colon is essential for the diagnosis of this condition. When one presents complaints suggestive of a large bowel lesion, the physician may be suspicious of a condition of multiple polyposis,

FIGURES 2—6 ARE SECTIONS OF POLYPI TAKEN FROM PATIENT 1. THEY ILLUSTRATE STAGES IN THE DEVELOPMENT OF INTESTINAL POLYPI. (LOW POWER AND HIGHER MAGNIFICATION ARE SHOWN.)

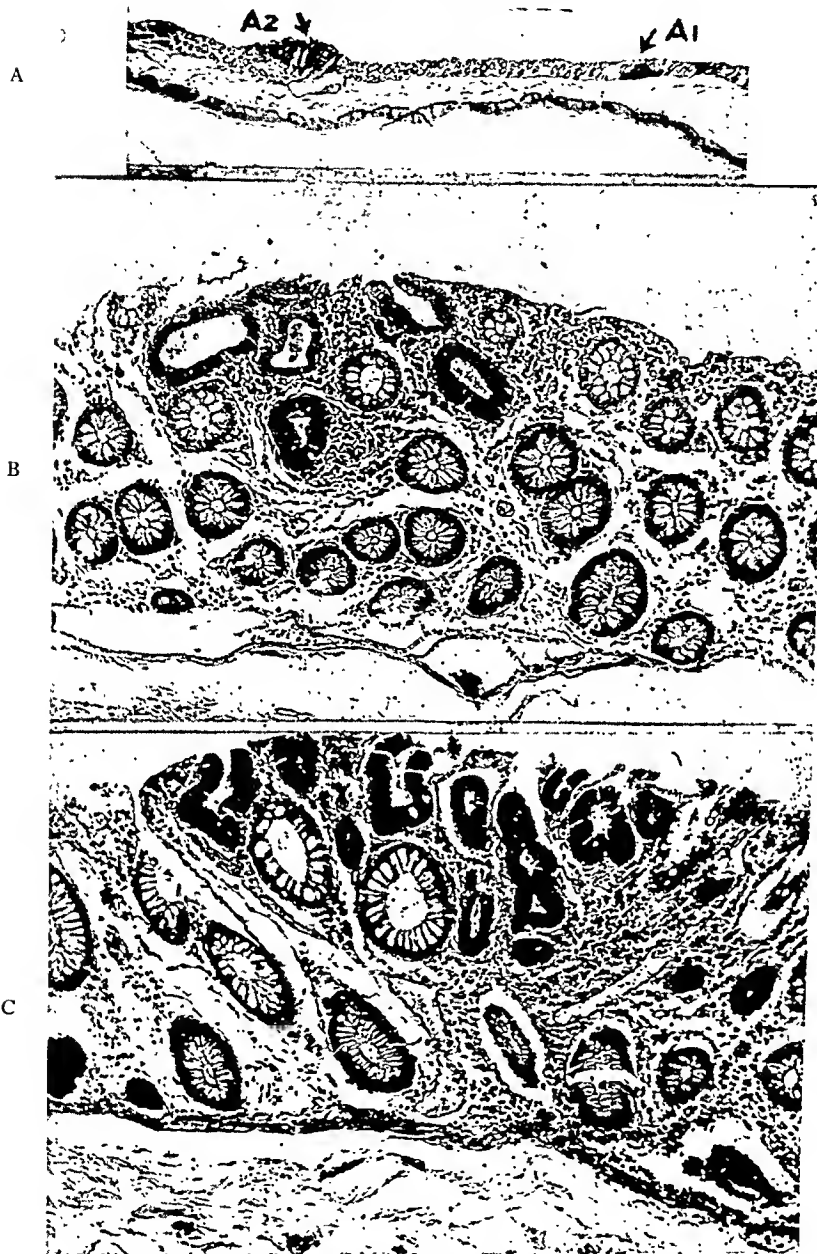


FIG. 2.—A is a low power view of a section of the wall of large intestine showing beginning of polypi at two places A1 and A2. A1 is a barely visible, slightly darker area, surrounded by normal mucosa. A2 is a larger more elevated area.

B is a magnification of A1 and shows very slight thickening of the mucosa due to fairly localized infiltration of small round cells. The cells of these glands do not contain or secrete any mucus and stain rather deeply. The nuclei are more prominent, slightly hyperchromatic, with a suggestion of loss of polarity.

C is a magnification of A2. The changes are slightly further advanced. Round cell infiltration is present and abnormal glands are more numerous.

## POLYPOSIS OF THE COLON

but since there are no symptoms pathognomonic of polypi of the colon, the above complete studies must be done to make this diagnosis.

Any patient with complaints referable to the lower bowel should have a digital, proctoscopic and sigmoidoscopic examination as a minimum. In multiple polyposis of the colon, polypi can be felt digitally and seen through the proctoscope and sigmoidoscope. There is no difficulty in detecting polypi

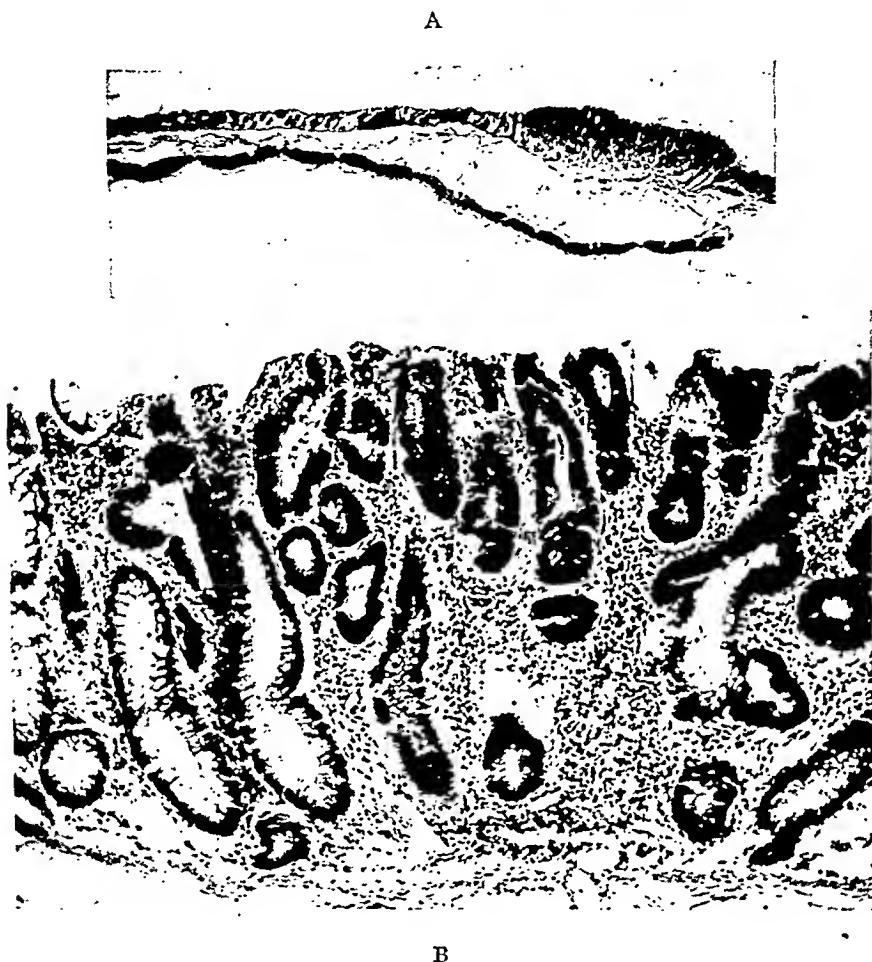


Fig. 3.—A is a low power view of a definite polypus formation with the beginnings of a connective tissue core.  
B. High power magnification of A. This shows the junction of polypus with fairly normal mucosa.

through the sigmoidoscope. They may be pedunculated in nature or simply elevations of the mucous membrane. Often they appear in clumps and are variable in size.

If polypi are felt on digital examination or seen through the sigmoidoscope, roentgenologic examination of the colon is indicated. Before a barium enema is given, the colon must be absolutely clean, since polypi can be hidden from view by fecal particles. We give routinely an ounce of castor oil the night before the examination and an enema the morning of the examination. To adequately and completely demonstrate polypi of the colon, the barium enema should be followed by postevacuation films and then by air insufflation

and double contrast films. Figure 7 shows roentgenologic studies performed on one of our patients; the value of double contrast films is well illustrated.

It is important to realize that an individual with multiple polyposis of the colon may also have a lesion in the stomach or small intestine. One of our cases had a carcinoma of the stomach, and several cases have been reported in the literature of an isolated polypus in some portion of the small intestine.



Fig. 4.—A is a low power view of a flat, fairly sharply defined elevation surrounded by normal mucosa.  
B. Magnification of A. The changes are essentially the same as in Figure 3B. There are a few hyperemic capillaries.

For this reason, we recommend roentgenologic examination of the stomach and small intestine in an individual with multiple polyposis.

The possibility of a malignant change is often suggested by roentgenologic examination. Likewise, the evidence of malignancy, if present, may be obtained from a biopsy of a polypus. A biopsy should always be taken of a suspicious appearing polypus.

## POLYPOSIS OF THE COLON

### TREATMENT

The treatment of congenital polyposis of the colon is a surgical problem. Surgical removal of the involved colon offers the only hope of permanent relief to those individuals with this disease. This statement is made because it is a well-known fact that polypi of the colon tend to undergo malignant changes. The affected portion of the bowel must be removed. The surgical treatment of this disease has undergone many changes and advances. Ileostomy, which was the first form of treatment, evidently was not the answer. It merely prolonged the agony, as it was usually done late

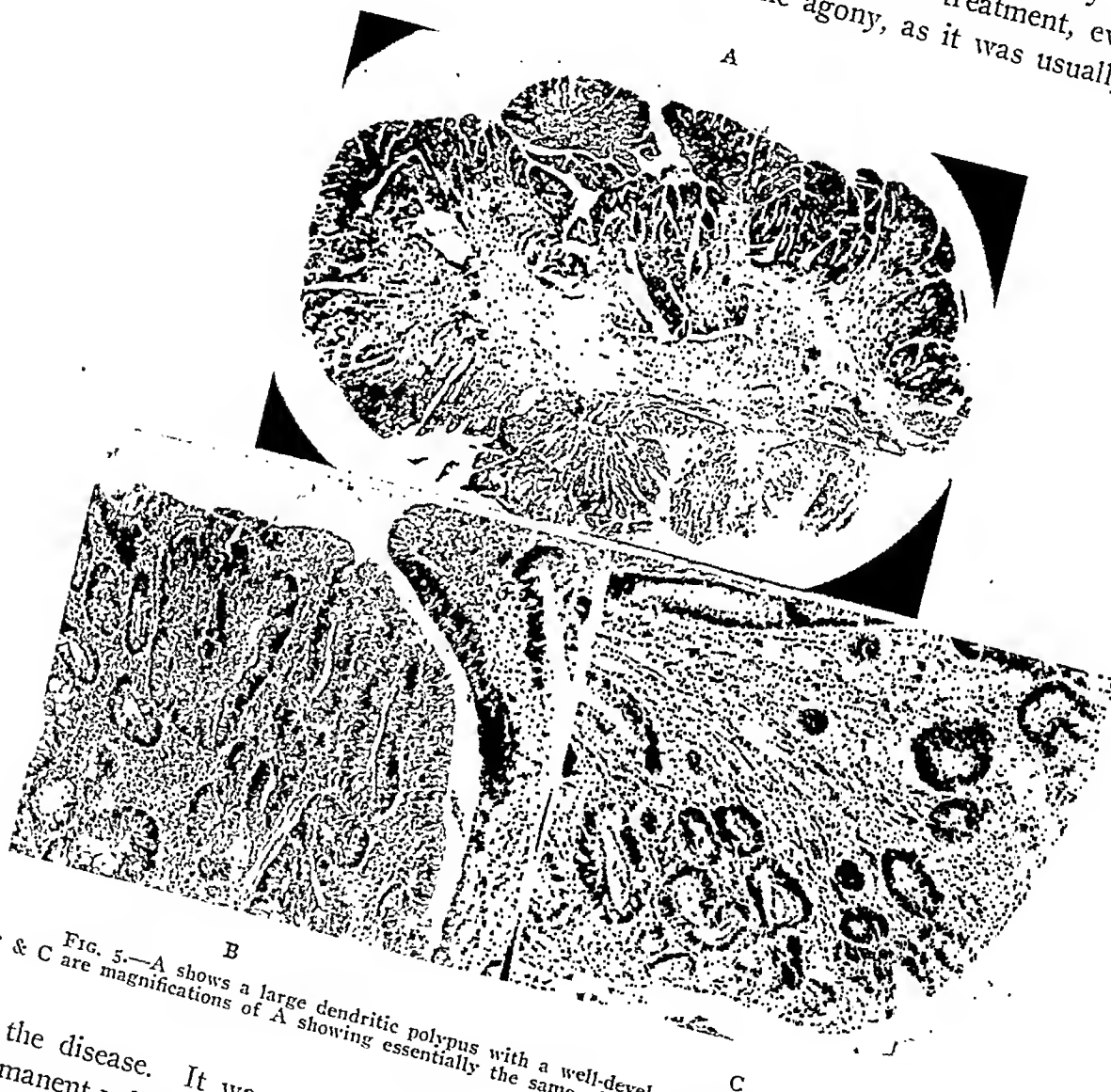


FIG. 5.—A shows a large dendritic polypus with a well-developed connective tissue core. B & C are magnifications of A showing essentially the same picture described above on a larger scale.

in the disease. It was soon realized that in order to obtain anything of a permanent value, it was necessary to remove the affected portion of the bowel. Ileostomy, followed by total colectomy, then became the procedure of choice. This was not totally satisfactory because many individuals could not satisfactorily tolerate a permanent ileostomy.



Our mode of treatment of these cases is not original, but we believe that it is the most logical and satisfactory method. Our plan is as follows: The polypi in the rectum and rectosigmoid area are destroyed by fulguration. Following this an ileorectosigmoidostomy is performed; and finally a colectomy down to the anastomotic site is done. In this plan the normal outlet of the rectum and its sphincters is preserved, and as Mayo and Wakefield<sup>4</sup> state, the rectosigmoid and sigmoid flexure, which contain the nervous mechanism which controls the desire to defecate, are left intact. A schema of the plan of treatment is shown in Figure 8.



FIG. 6.—High power view showing a few polypi containing numerous irregular glands, the lining cells of which are all goblet cells.

The purpose of fulguration is to clear the rectum of offending polypi. We attempt to fulgurate the polypi as far up the bowel as can be reached by the sigmoidoscope. It is essential that the rectum and sigmoid be clean at the time of fulguration. Enemata are given until clear the night before the procedure. No anesthetic is given since the full coöperation of the patient is necessary. The patient is placed in the prone, inverted position. We believe that the patient should be hospitalized because hemorrhage and perforation may occur when diathermy is applied to this portion of the bowel. These two complications usually occur 5–10 days after fulguration. It is not possible to say how many polypi may be fulgurated at a time or how frequently fulgurations should be performed. These depend on many factors. Some patients can tolerate the procedure better than others. Likewise, the healing process in the mucous membrane of the rectum varies in different individuals.

We have found that if fulgurations are performed more frequently than every three days, the mucous membrane will still be inflamed and edematous, and the individual will suffer discomfort. As a rule, however, individuals withstand fulguration of the polypi quite well. We usually fulgurate for 30 to 45 minutes unless the patient complains of fatigue before that time. Following fulguration, the patient may develop a mild fever and low abdominal pain, but these usually quickly disappear. We have had neither hemorrhage nor perforation as a complication.

After we are satisfied that the polypi for a sufficient distance have been removed by the method of fulguration, we allow the patient to go home for at least a month. This is done to allow the inflammation incidental to the fulguration to subside. During this period at home, the patient is urged to follow a high-vitamin, high-caloric diet, and to get plenty of rest and sunshine. Supplementary vitamins are prescribed.

When the patient returns to the hospital, he is again sigmoidoscoped. If the lower segment of the bowel appears satisfactory and the general condition of the patient is good, an ileorectosigmoidostomy is performed. It has been proposed to do a hemicolectomy<sup>4</sup> at this stage, but since the most hazardous part of this procedure is to establish an anastomosis of the ileum with the terminal bowel, we prefer not to complicate this stage with an hemicolectomy. Continuous spinal anesthesia is employed. The terminal ileum is anastomosed to the upper end of the segment of sigmoid that had been freed of polypi by fulguration. An end-to-side anastomosis is the one of choice. A six-inch segment of the terminal ileum is removed in order to more easily swing the distal end of the ileum over to the site on the rectosigmoid. Two to three weeks later, depending on the postoperative course of the patient, the remaining colon is removed down to just above the anastomosis between the ileum and rectosigmoid, the latter being closed. It is important to know that after fulguration polypi may appear from time to time, and these have to be removed by fulguration. Lewis<sup>11</sup> reported a case that is illustrative of this point.

Buie<sup>25</sup> recommends performing the colectomy first, and then, if the patient survives, the rectum and rectosigmoid may be prepared by fulguration and later ileosigmoidostomy performed. He advocates this particularly because in some cases the patient goes through endless time, discomfort and preparation by fulguration only to succumb when colectomy is performed. If this plan is followed, the patient has a temporary ileostomy, and often this is difficult to handle.

Some men have reported the use of roentgenotherapy in these cases. VanZant<sup>26</sup> employed roentgenotherapy in two cases, with marked symptomatic relief and reduction in the number and size of the polypi. McKenney<sup>10</sup> reported similar results in ten cases treated by roentgen ray. According to McLaughlin,<sup>13</sup> no five-year cures have been reported that were treated by roentgen ray, and severe systemic reactions have occurred. The basis for the employment of roentgenotherapy is that hyperplasia of the lymphatic



C

B

A

FIG. 7.—X-ray films of Patient No. 3.  
A. Barium enema study. A large polypus is visible in the descending colon.  
B. Postevacuation film.  
C. Film taken after air-insufflation.

tissue and lymphatic infiltrations are present, and these are both susceptible to the roentgen ray.

The following five cases are reported, four of which have a definite hereditary background.

#### CASE REPORTS

**Case 1.**—E. H., a 29-year-old male, from Mississippi, was admitted to the Service of Dr. Damon B. Pfeiffer, at the Abington Memorial Hospital, August 5, 1942, with a chief and only complaint of diarrhea. He stated that this diarrhea began eight years ago and was characterized by three to four movements per day, the stools being loose, containing mucus but no blood. Five years ago he began to have severe abdominal cramps. Roentgenologic examination of the stomach at that time was negative. A proctoscopic examination revealed "growths in his rectum," as he expressed it. Shortly after this, in 1937, he decided to go to a large clinic for a check-up.

After a complete gastro-intestinal study had been done, he was told that he had multiple polypi of his colon and rectum. It was decided to fulgurate these polypi from his rectum and sigmoid, and after this was completed to do a colectomy. For two or three times a week for two months, fulguration of these polypi was performed. Because of financial difficulties, the patient left and returned home. His diarrhea had decreased in intensity to two, or less, movements a day, the stools being more formed, containing mucus but no blood. The abdominal cramps disappeared, and his weight was maintained.

Following this, his weight increased 45 pounds in one year. For the next four years his physical condition was excellent. In 1940, a gastro-intestinal series was repeated, and his local physician advised against operation. A year later the diarrhea returned, the stools numbering three to six per day. He began to suffer from abdominal cramps again, and a gradual weight loss occurred. In addition, he began to have rectal bleeding. The intestinal roentgenologic examination was repeated, and some of the polypi appeared to have increased in size, and operation was advised.

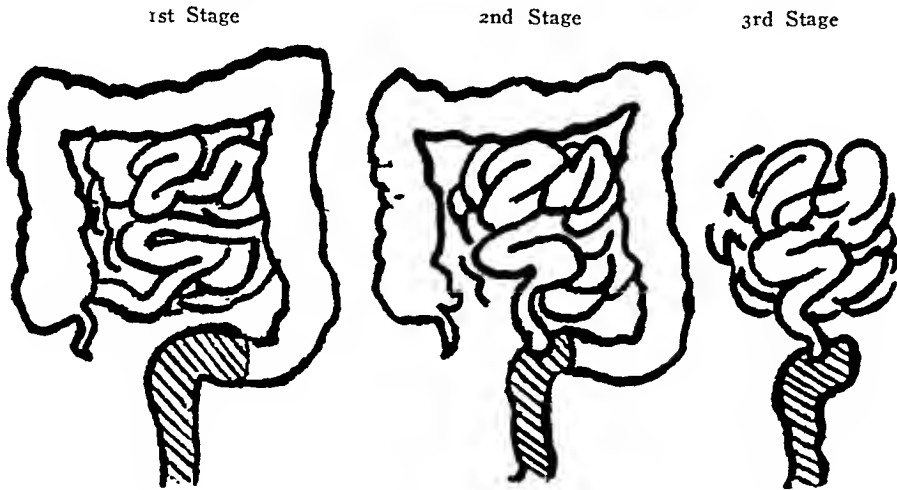
Further questioning revealed that the patient was an only child. His mother had died of "cancer of the bowel," 13 years ago, as did his maternal grandmother. The patient thinks that his maternal aunt has a similar condition. We have no proof of these facts, other than what the patient has told us. His father was given a clean bill of health. The hereditary background is shown in Figure 9.

*Physical Examination:* General examination at the time of admission to our hospital revealed a 29-year-old white male, 5 feet 10 inches tall, weighing 125 pounds. He appeared in excellent health. Examination of the heart and lungs was negative, as was the abdominal examination. Digital examination of the rectum, likewise, was negative. Proctoscopic and sigmoidoscopic examinations revealed this portion of the large intestine to be negative, except for one polypus just above the rectosigmoid area. The blood count and other laboratory studies were within normal limits.

*Course in Hospital:* On August 7, 1942, (two days after admission), an ileorecto-sigmoidostomy was performed upon the patient by Dr. Damon B. Pfeiffer. Pre-operatively, the patient was given succinylsulfathiazole. His postoperative course was uneventful. Wangenstein drainage was maintained for three days postoperatively, and parenteral fluids were given for six days postoperatively.

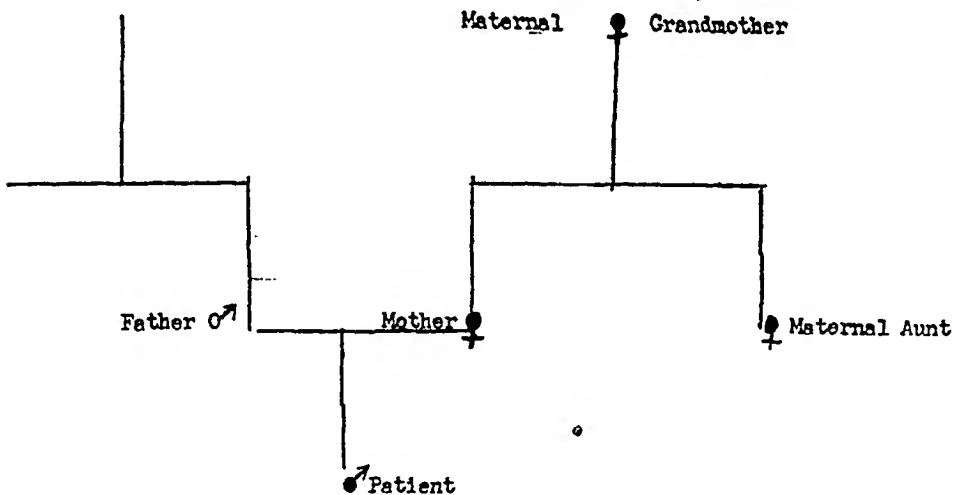
On August 26, 1942 (19 days after the first operation), a second operation was performed—the procedure anticipated being a total colectomy. The anastomotic site was found to have been pulled over toward, and attached to, the terminal ileum and cecum by adhesions. A pocket of purulent material was found at this site, so it was decided that it would be unwise to try to free the adhesions. Therefore, the colon was resected from just proximal to the anastomotic site on the sigmoid, to within three or four inches of the blind stump of the ileum, leaving the terminal ileum and cecum *in situ*.

The cecum was brought out at the midportion of the incision. On the operating table, the patient received 750 cc. of blood plasma, and, later, 500 cc. of blood. For two weeks postoperatively he ran a slight elevation of temperature, but otherwise his condition was excellent. He had one to two normal bowel movements per day. His incision healed well, and he was discharged on September 23, 1942 (seven weeks after admission),



Fulguration of polyps                      Ileorectosigmoidostomy                      Colectomy

FIG. 8.—Schema of surgical treatment of multiple polyposis of the colon.



- ♂ - Male free of disease of the colon
- ♂ - Male suffering from multiple polyposis of the colon
- ♀ - Female suffering from some disorder of the G.I. tract.

FIG. 9.—Family tree of Patient No. 1.

stating that he had better control of his intestinal tract than ever before. A digital examination of the cecum, just before discharge, revealed several small polypi to be present in this loop of bowel. These were removed by fulguration. The patient returned in July, 1944, and the cecum was removed under spinal anesthesia.

COMMENT.—The treatment in this case followed the plan outlined above. Following operation, the patient gained weight, had normal bowel movements

and offered no complaints. It is extraordinary that with so small a portion of the bowel remaining to serve as a receptacle for the fluid ileal contents, no diarrhea or irritation has resulted, and the patient reports that he has only one or two evacuations per day.

**Case 2.**—J. H., a white male, age 29, was admitted on the Surgical Service of Dr. Damon B. Pfeiffer, at the Abington Memorial Hospital, March 16, 1943, with a chief complaint of blood stools. Five months previous to admission, he began to complain of an "upset stomach." Foods did not agree with him, his appetite became poor, and he was occasionally nauseated. Since that time he had infrequently noted mucus in his stools and diarrhea. For three weeks before admission he had intermittent attacks of gas pains. During this three-week period he had noted blood in his stools daily and had one severe hemorrhage by rectum. No vomiting had occurred. A weight loss of ten pounds had occurred during the three weeks previous to admission. The remainder of his history was negative, except that his mother had died of "cancer of the intestines." On subsequent questioning of the patient's father, it was found that the mother had an intestinal malignancy, plus multiple polyposis of the colon. This hereditary background is shown in Figure 10.

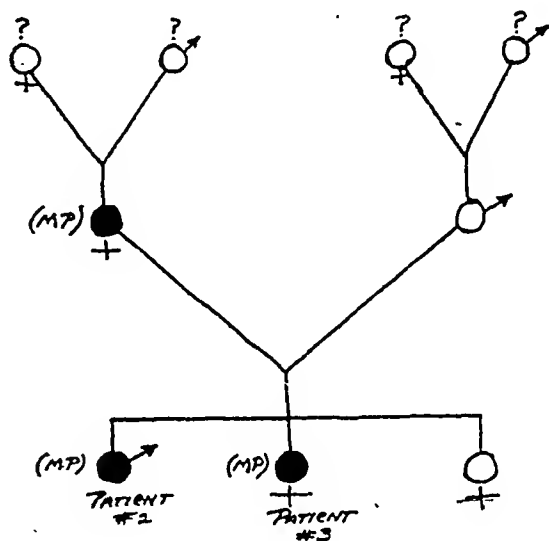


FIG. 10.—Family tree of Patients 2 and 3.

**Physical Examination:** This revealed a thin, pale, 29-year-old male, in no evident distress. Temperature, pulse and blood pressure were normal. The physical examination was entirely negative, except for many small polypi in the rectum, which were felt on digital examination.

**Laboratory Data:** Hemoglobin 88 per cent; white blood cells 7,400, with 58 per cent polymorphonuclears, 36 per cent lymphocytes, 1 per cent monocytes and 5 per cent eosinophils. Blood urea nitrogen 13; fasting venous sugar 80. Wassermann and Kahn negative. Urine negative, except for an occasional white blood cell per H.P.F.

**Course in Hospital:** A barium enema had been given to the patient at another hospital, and multiple polyposis of the colon was found to be present. Two days after admission, the patient was proctoscoped, and numerous pedunculated and sessile polypi were observed. Fulgurations were then performed as frequently as possible, although the patient was not very coöperative. Occasionally he would leave the hospital for several months.

On August 15, 1943, a mass became palpable in the left lower quadrant of the abdomen just above the outer half of the iliac crest. The patient's temperature remained normal, and the question arose whether this mass was an abscess secondary to fulguration or whether it was a malignancy of the sigmoid. A barium enema was done, and in addition to multiple polyposis throughout the colon, there was an irregularity in the contour of the sigmoid just above the level of the inferior margin of the sacro-iliac joint. This covered an area three centimeters long and 15 millimeters wide. The fulgurations were continued every two days, and the mass diminished greatly in size.

On October 15, 1943, the patient went home and did not return to the hospital until May 4, 1944, at which time four more fulgurations were performed, and the lower sigmoid, rectum and anus for a distance of seven to eight inches was now free of polypi.

On May 22, 1944, an exploratory celiotomy was performed under continuous spinal anesthesia, supplemented by intravenous sodium pentothal. A firm, indurated lesion was found at the junction of the rectum and sigmoid and was unquestionably malignant. The lesion was bound down to the posterior parietal peritoneum and had infiltrated the bladder. The intestine distal to the lesion was free of polypi on palpation, but the large intestine proximal to the lesion contained innumerable polypi. The liver was free of metastasis. The findings were otherwise negative. To liberate the malignant area, the posterior half of the bladder had to be resected. The left ureter was found to extend into the malignant tissue, and it was therefore clamped, cut and ligated proximal to the lesion. The large intestine was severed between clamps distal to the lesion with the cautery, and the stump of the distal segment closed in the Parker-Kerr fashion. This lower segment of bowel was pushed down into the pelvis. The descending colon was then severed proximal to the lesion, and the lesion was thus resected. A single-barrel colostomy was performed. A drain was placed in the pelvis, and the abdomen was closed in layers.

The postoperative course was stormy, and on the 12th postoperative day the patient died. Autopsy revealed extensive peritonitis.

COMMENT.—This patient's family history was investigated thoroughly, and is shown in Figure 10. His mother evidently suffered from the same disease entity. Later his sister was found to also have multiple polyposis of the colon. This patient was a problem in that he would leave the hospital and not return until several months later. We had contemplated doing an ileorectosigmoidostomy after the fulguration of the polypi and then a colectomy, but the findings at operation nullified these plans.

Case 3.—H. S., white, female, age 21, sister of J. H. (Case 2), was admitted to the Abington Memorial Hospital November 15, 1944. For five to seven years she had been suffering from diarrhea, and had noticed that her stools were never formed. In addition, she had noticed blood in her stools during this same period of time. For several years she had experienced hunger pains. During the six months preceding admission she had lost ten pounds in weight, although her appetite remained good. For several months, mucus had been present in the stools. Nausea occasionally occurred, but no vomiting. On June 4, 1944, her brother (Case 2) had succumbed following an abdominal operation for multiple polyposis of the colon, and this fact prompted her to go to a physician. Her hereditary background with relation to congenital polyposis is shown in Figure 10. A barium enema showed multiple polyposis of the colon (Fig. 7). At the time she was pregnant. A therapeutic abortion was deemed advisable, and this was performed on November 16, 1944.

The patient experienced the usual childhood diseases. At the age of three she had pneumonia, and two years ago she suffered from secondary thrombocytopenic purpura. She had undergone no operations.

Her mother died of "stomach trouble," which on investigation was found to be multiple polyposis of the colon. Her brother died following an operation for multiple polyposis of the colon and carcinoma of the rectosigmoid area.

*Physical Examination:* Patient was a pleasant appearing 21-year-old white female, who was two months pregnant. Temperature, pulse, respirations and blood pressure were normal. She was fragile in appearance, but in no acute distress. Her physical examination was negative, except for slight enlargement of the uterus, and the presence of multiple polypi of the rectum, as revealed by digital and proctoscopic examinations.

*Laboratory Data:* Hb. 11.4 Gm., 75 per cent; R.B.C. 3,630,000; W.B.C. 8,700, with 68 per cent polys, 29 per cent lymphs, and 3 per cent monos. Wassermann and Kahn negative. B.U.N. 10, fasting venous sugar 75. Uranalysis revealed a faint trace of albumin, 2-4 W.B.C. and an occasional R.B.C. per high power field.

*Hospital Course:* On November 16, 1944, a therapeutic abortion was performed. She recovered uneventfully from this, and on November 21, 1944, was transferred from the Gynecologic Service to the Surgical Service. On November 22, 1944, the junior author began the arduous task of fulgurating the polypi in the rectum and sigmoid. The polypi were countless in number. They were both sessile and pedunculated in nature, and varied from a few millimeters to 0.5 cm. in diameter. Fulguration was performed three times a week, and after ten fulgurations the lower bowel from the anal orifice to rectosigmoid was free of polypi. She was discharged on December 12, 1944, for one month to allow the inflammation incidental to the fulgurations to subside. On January 22, 1945, she was readmitted to the hospital. Sigmoidoscopy was performed and the mucosa of the rectum and sigmoid was normal, except for several small polypi which were fulgurated. She was discharged the following day.

On January 30, 1945, she was readmitted to the hospital, and on February 5, 1945, under continuous spinal anesthesia, an end-to-side ileorectosigmoidostomy was performed. A segment of the terminal ileum was removed also at operation. On February 24, 1945, she was discharged after a satisfactory convalescence. Excellent control of bowel habit was obtained, the stools numbering two to three per day, being well formed. On April 2, 1945, patient was readmitted, and two days later a colectomy was performed down to the anastomotic site. The operation was facilitated by the fact that the small intestine was decompressed by a Miller-Abbott tube that had been inserted the day before operation. The patient developed an intestinal obstruction ten weeks after operation. An exploratory celiotomy was performed. The ileum was found obstructed, due to adhesions. The adhesions were liberated. A satisfactory convalescence occurred.

COMMENT.—This case followed our desired method of treatment from beginning to end. Patient appeared in good physical condition after the final operation. Sigmoidoscopy is to be performed at regular intervals, however.

**Case 4.**—E. F., a 42-year-old white male, was admitted to the Abington Memorial Hospital, March 10, 1943, with a chief complaint of constipation. For three days the patient had been having crampy, abdominal pains, vomiting, tenesmus, and inability to have a bowel movement. There was no history of weight loss, food intolerance, melena or mucus in stools or change in the bowel habit prior to the present constipation.

Past medical history was negative except for bilateral herniorrhaphy five years previously. There had been no serious illnesses in his family. No one had suffered from intestinal disorders to his knowledge.

*Physical Examination:* Patient was quite apprehensive. His skin was dry and he appeared somewhat dehydrated. Otherwise the examination was negative, except for slight tenderness on the left side of the abdomen. In addition, many small polypi were palpated on rectal examination.

*Laboratory Data:* Hb. 75 per cent, W.B.C. 8,400, with 74 per cent polys. B.U.N. was 16, chlorides 550, CO<sub>2</sub> 62, venous sugar 86. Wassermann and Kahn negative. Urinalysis was normal. Sigmoidoscopic examination revealed many small pedunculated and sessile polypi in rectum and rectosigmoid. A barium enema revealed a filling defect involving a segment of the sigmoid at least 9 cm. in length.

*Hospital Course:* Five days after admission, an exploratory celiotomy was performed. The lesion seen roentgenographically was malignant, but there was no evidence of metastasis. Small polypi were present throughout the colon. The lesion was resected, a descending single-barrel colostomy performed, and the distal segment of bowel closed. After recovery from this operation, barium was injected through the colostomy, and multiple polypi were found scattered throughout the large intestine. The patient was then subjected to frequent fulgurations and the lower loop, which included the rectum and rectosigmoid was, thus, freed of polypi. On June 7, 1943, three months after



the first operation, an ileorectosigmoidostomy was performed. He was discharged three weeks following this operation. Twice he returned with signs of obstruction, each time a left pelvic abscess being present. Decompression of the intestine with a Miller-Abbott tube, and an incision and drainage of the abscess gave relief on each occasion. On March 29, 1944, approximately one year after the first operation, another exploratory celiotomy was performed, and the distal end of the ileum and the remainder of the colon was removed. Since then he has been followed in the Surgical Out-patient Department. Rectal examination now reveals evidence of recurrence.

COMMENT.—This patient had no symptoms referable to his colonic polypi and did not seek medical advice until a malignancy had occurred, with partial obstruction.

Case 5.—A white male, age 56, was admitted to the Lankenau Hospital, Philadelphia, Pa., on November 29, 1944, with a chief complaint of indigestion. Two years ago vague indigestion developed. He had experienced burning in his stomach for several years, relieved by food. Loss of appetite and easy fatigue had been present for six months. He had lost 15 pounds in six months. Three weeks ago, epigastric pain and vomiting occurred. No history of diarrhea, constipation, mucus or blood in stools.

His mother died at the age of 83, with "stomach trouble." One son was discharged from the Army because of "stomach trouble." Roentgenologic examination of his daughter revealed multiple polyposis of the colon.

*Physical Examination:* A middle-aged white male, extremely pallid and quite emaciated in appearance. Physical examination was negative, except for slight upper abdominal distention and several polypi palpable on rectal examination.

*Laboratory Data:* Hb. 31 per cent, R.B.C. 1,860,000, W.B.C., 18,500, with 75 per cent polys. Wassermann and Kahn were negative. Blood chemistry studies revealed B.U.N. 12, blood chlorides 494, serum protein 5.24, blood sugar 74, prothrombin 80 per cent. Stool examination was positive for occult blood. Urinalysis was normal.

*Hospital Course:* On sigmoidoscopic examination, scattered polypi were observed in the rectum. Roentgenologic studies revealed a filling defect involving the gastric antrum, and polypi in the rectum, sigmoid, transverse colon and cecum.

After frequent transfusions of blood and serum, an abdominal exploration was done. A carcinoma, involving the distal third of the stomach, was found. Likewise, polyposis of the colon existed. Subtotal gastrectomy was performed. The post-operative course was uneventful.

COMMENT.—It is extraordinary that this patient had no symptoms referable to his polypi. There seems to be an hereditary tendency to polyposis in this family, since his daughter was shown to have this disease on roentgenologic examination. There is a possibility that both his mother and son had the same condition, but we have no definite proof of this as yet.

#### SUMMARY

1. Five cases of multiple polyposis of the colon are reported, four of which have a definite hereditary aspect.

2. The classification, etiology, pathology, symptoms, diagnosis and treatment of congenital multiple polyposis are discussed, and special emphasis is placed on the tendency of the polypi to undergo malignant changes.

### CONCLUSIONS

1. In every individual who is found to have rectal polypi, complete study of the intestinal tract is necessary. This includes proctoscopic and sigmoidoscopic examinations, barium enema studies, which include postevacuation films and double contrast studies; and, finally, roentgenograms of the stomach and small intestine.

2. The family history of every individual with multiple polyposis of the colon should be thoroughly investigated, since this condition is often on an hereditary basis.

3. Early diagnosis and treatment is very important, for intestinal polypi tend to become malignant.

4. A satisfactory plan of treatment includes fulguration of the polypi in the anus, rectum and sigmoid, followed later by ileorectosigmoidostomy and finally by colectomy.

5. The outlook for these patients is good if treatment is begun early.

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# THE LOCAL USE OF SULFANILAMIDE IN THE TREATMENT OF ACUTE APPENDICITIS\*

A REVIEW OF 1481 CASES

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THE PROGRESSIVE IMPROVEMENT in mortality rates in many surgical conditions has been most evident during the past five years. The reduction in mortality figures is especially marked in acute appendicitis and its complications, namely, peritoneal abscess and peritonitis.

Improvements in operative technic play only a small part since appendectomy is a fairly standardized procedure except for the more frequent use of the McBurney incision. Some credit can be given to the advances made

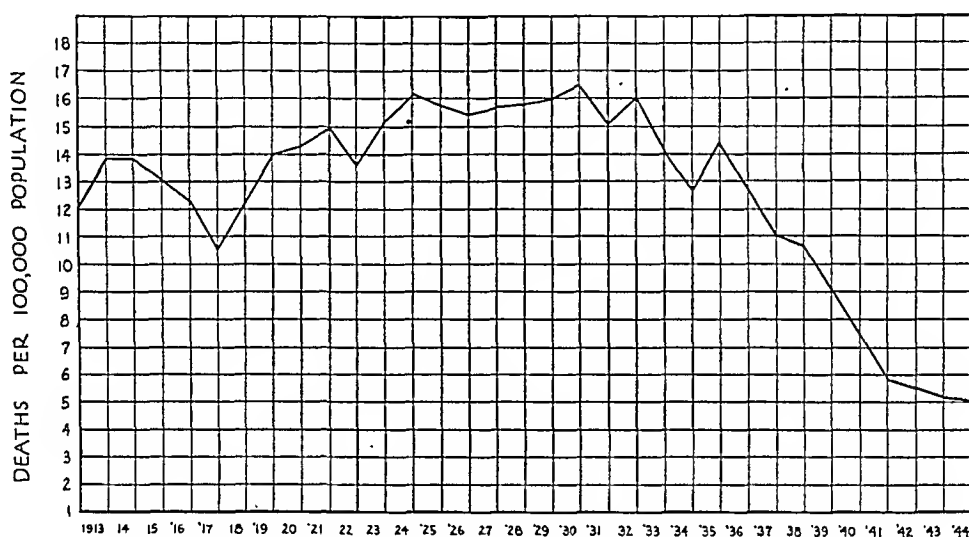


CHART 1.—Made from statistics from Bureau of Vital Records and Statistics, Department of Health, City of New York.

in the use of anesthesia, and the better understanding of the problems of the surgical patient, such as fluid and chemical equilibrium and intestinal drainage. Naturally, these factors are responsible, to some degree, in lowering the mortality and morbidity figures, but, undoubtedly, the greatest factor has been the use of the sulfonamide drugs whether used locally, parenterally, or orally. It is becoming rare, indeed, for a case of peritonitis to die, unless the patient has been brought to a hospital late in an advanced stage of peritonitis. Penicillin is also proving of some value, but, since the predominating organism is *Bacillus coli*, the main reliance is placed on the sulfonamide drugs. However, all severe forms of acute appendicitis with abscess or peritonitis do best when penicillin is given in addition to the sulfonamides for its effect on the other organisms frequently present with *Bacillus coli*.

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In the majority of hospitals, the more severe cases of appendicitis and its complications are treated with sulfanilamide placed locally in the peritoneal cavity at the time of operation. In other institutions the surgeons feel this is unnecessary and give it postoperatively, by oral or parenteral routes. We feel that fewer toxic effects of the drug are seen when it is used locally. A great concentration, many times that of the blood, is advantageous in the peritoneal fluid as soon as a few hours, postoperatively. Such concentration can only be obtained in this manner. We believe that this method enables wounds to heal faster and results in fewer complications.

Sulfanilamide was first used intraperitoneally in acute appendicitis at Roosevelt Hospital January 10, 1940.<sup>1</sup> The results after five years are now

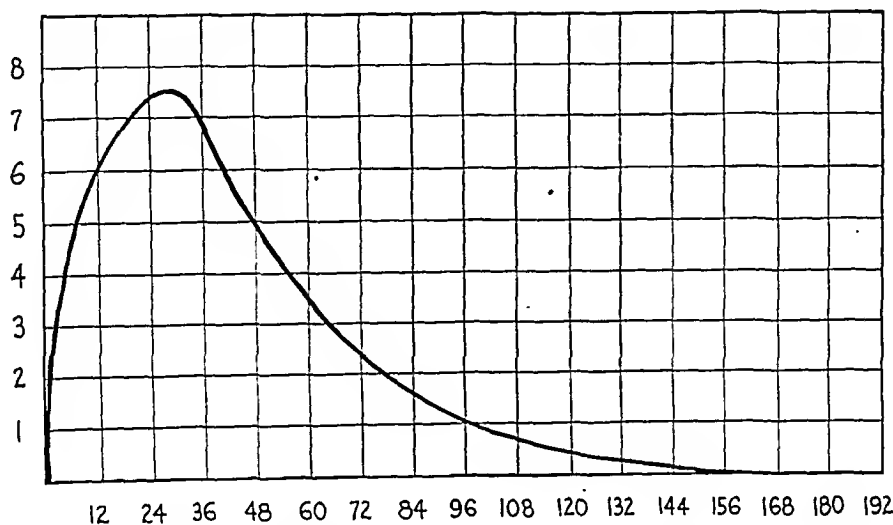


CHART 2.—Average blood level in 25 cases of peritonitis and peritoneal abscess. 6-12 grams sulfanilamide used intraperitoneally.

presented and compared with the results of the five-year period before January, 1940. In comparing the two five-year periods a simple classification of appendicitis and its complications is used. By this means we avoid the many confusing terms used in describing the types of lesions seen in appendicitis, which, ordinarily makes it difficult to accurately compare any group of appendicitis cases. The cases are classified in the following manner:

Group 1. Acute appendicitis. Here there is no gross perforation, and peritoneal fluid, if present, shows no growth. If the appendix is gangrenous, it is still placed in this group.

Group 2. Acute appendicitis with localized abscess formation.

Group 3. Acute appendicitis with peritonitis. This group includes not only

Lt. Col. James E. Thompson, M.C., A.U.S., collaborated with the author in a preliminary report on this subject J. A. M. A., 118, 189-193, January 17, 1942. Lt. Col. Thompson has been over-seas with the Ninth Evacuation Hospital (The Roosevelt Hospital Unit) for the past three years.

# SULFANILAMIDE IN ACUTE APPENDICITIS

the cases of spreading, diffuse, and general peritonitis, but also those of the localized variety. It is believed impossible to obtain a true knowledge of the extent of peritonitis through a McBurney incision, which was used in 96 per cent of our cases in both series. The impression would vary with the individual surgeon and could be accurately determined only after an exploratory incision. Cases classed as peritonitis must show a positive culture.

TABLE I  
ACUTE APPENDICITIS SERIES: 1935-1939

Type	Cases	Deaths	Mortality Per Cent
Acute.....	566	3	0.53
Abscess.....	59	4	6.78
Peritonitis.....	117	14	11.96
Total....	742	21	2.83

TABLE II  
ACUTE APPENDICITIS SERIES: 1940-1944

Type	Cases	Deaths	Mortality Per Cent
Acute.....	573	0	0
Abscess.....	56	2	3.57
Peritonitis.....	110	1	0.91
Total.....	739	3	0.40

In both of the above series only the cases of acute appendicitis are included that were so diagnosed by the pathology laboratory. All cases of the sub-acute and questionable acute variety were discarded. Many cases diagnosed as acute at operation failed to be so diagnosed after section in the Pathology Department. Bacteriologic findings in the above groups of cases showed *Bacillus coli* as the predominating organism in 83 per cent of the positive cultures. Other organisms encountered as etiologic factors in order of frequency, were *gamma Streptococcus*, *beta Streptococcus*, *Staphylococcus aureus* and *albus*. Sometimes associated with *Bacillus coli*, and the other organisms, were *Bacillus lactis aerogenes* and *Bacillus mucosus capsulatus*.

TABLE III  
ANALYSIS OF DEATHS: 1935-1939

	Deaths
Peritonitis.....	13
Pneumonia.....	3
Pylephlebitis and septicemia.....	2
Pulmonary embolism.....	1
Cardiac decompensation.....	1
Acute purulent cystitis.....	1
Total.....	21

TABLE IV  
ANALYSIS OF DEATHS: 1940-1944

	Deaths
Peritonitis, shock.....	1
Thrombosis iliac artery, shock.....	1
Postoperative pneumonia, aspiration of vomitus.....	1
Total.....	3

A glance at Table III shows the cause of death in the 21 cases in the first five-year group, but, needless to say, the majority was directly due to peritonitis. In the second series, from January, 1940, through December, 1944, representing a similar five-year period, there were only three deaths in 739 cases of acute appendicitis and its complications, a mortality of 0.4 per cent. Sulfanilamide was used locally in 320 of the 739 cases, or 43.3 per cent of the total. These represented the more severe varieties of the disease. The average amount of the drug used locally in the adult cases was nine grams, two-thirds of the total amount of the drug being sprinkled in the peritoneal cavity and the remainder distributed in the wound layers. In the more severe cases of acute appendicitis without abscess or peritoneal involvement, four grams only were used, but, in the severe cases of abscess or peritonitis, we did not hesitate to use 12 grams. In those patients in whom sulfanilamide was used, the ages ranged from one year to 80 years. No definite toxic effects were seen except some cyanosis. There were no cases of leukopenia or agranulocytosis, but there were two cases of mild jaundice. In one of these cases the jaundice was felt to be definitely due to infection, as it disappeared under continued administration of sulfonamide by mouth. In 48 of the cases that received sulfanilamide locally, the administration of sulfonamide was continued orally or intravenously, usually in the form of sulfadiazine. Persistent elevation of temperature did occur in a few cases, and in some of these we felt that the sulfanilamide was directly responsible.

In this series there has been an increasing tendency toward simple drainage, without removal of the appendix, in the desperately sick peritonitis cases, unless the appendix could be removed quickly and without any search. In 20 of the above cases the appendix was not removed at the original operation. This also gave us an opportunity to observe adhesion formation at the second operation when the appendix was removed. We have been consistently impressed by the relative absence of adhesions.

Postmortem examinations were done in two of the three cases listed in Table IV. The first case was a mistake in diagnosis, and was operated upon for intestinal obstruction on the second day after admission. The patient was only five feet tall and weighed 250 pounds. At operation, through a right rectus incision, a diffuse peritonitis was found. There was an opening at the base of the appendix through which gross fecal contamination had occurred. The patient died shortly after the operation. The second case was not autopsied, but this case died two hours after an unsuccessful attempt was made to do an embolectomy. The third case died on the fifth postoperative day, at which time pneumonia and ileus were complicating the picture. A Miller-Abbott tube was being substituted for a Levine tube, which caused the patient to vomit. Aspiration occurred and the patient died in a few minutes.

The complications in the 1940-1944 series were, in general, less than half those of the earlier series. We were fortunate in not having any cardiac deaths. There was a drop of over 50 per cent in secondary peritoneal abscesses,

but we feel some of the ten secondary abscesses could have been avoided, if the cases had been drained. We deplore the tendency of not draining the peritoneal cavity merely because sulfonamide therapy is used. The old rule "when in doubt, drain" should be adhered to as it was before the use of this drug. We firmly believe that the McBurney incision should be used in all cases where a diagnosis of acute appendicitis is made. Only in very rare instances is it necessary to make a second incision for more adequate exposure.

TABLE V  
COMPARISON OF IMPORTANT COMPLICATIONS

Type of Complication	1935-1939 (741 Cases)		1940-1944 (739 Cases)	
	Number	Percentage of Total Cases	Number	Percentage of Total Cases
Wound complication.....	85	11.5	33	4.46
Secondary peritoneal abscess.....	21	2.8	10	1.3
Atelectasis.....	16	2.1	14	1.9
Pneumonitis.....	12	1.6	6	0.81
Phlebitis.....	5	0.7	2	0.27
Pylephlebitis.....	2	0.27	0	0
Jaundice.....	1	0.13	2	0.27

In three per cent of our cases it was necessary to make a Weir extension. The McBurney incision makes for shorter operative time, quicker convalescence, fewer days in the hospital, and, in general, fewer complications. This incision was used in 96 per cent of the cases of both five-year series. It is the ideal incision for the severe peritonitis case where it is wise to leave the wound unsutured, except for the peritoneum. This cannot be done in a right rectus incision. Disruptions and postoperative herniae are not seen with a properly made McBurney incision. Drainage from a McBurney incision is better from a physiologic and anatomic standpoint, since the incision, as a rule, lies directly over, or near the pathology. Further, it is better to have the drain run from the pelvis or cecal area alongside the pelvic or lateral wall of the abdomen, rather than across loops of small intestine to emerge from a rectus incision.

A great deal of experimental work has been done in regard to the effects of sulfonamides used locally. When sulfanilamide is used properly in the correct dosage, and when it is distributed evenly throughout the wound, no interference with wound healing occurs, and the tensile strength of the wound is not diminished. We do not advocate the use of sulfathiazole and sulfadiazine locally, as we feel it is too slowly absorbed. We have used equal parts of sulfanilamide and sulfathiazole, but only in our drained peritoneal cases.

In severe peritonitis cases local anesthesia is often desirable and its use may avoid a fatal outcome. Preoperative medication with demerol and scopolamine undoubtedly aids the patient undergoing local anesthesia; frequently the patient does not remember being in the operating room. In a small number of cases it has been necessary to use small amounts of pentobarbital sodium intravenously toward the end of the operation. Use of



the oxygen positive pressure mask for 12 to 24 hours postoperatively will diminish the occurrence of atelectasis and pneumonitis and help the patient from a circulatory standpoint. The positive pressure mask, with its high concentration of oxygen, is an aid in the treatment of postoperative distention, in addition to the usual intestinal suction. Some of the more recent positive pressure masks have an opening in the apparatus which provides for the insertion of a Levine or Miller-Abbott tube.

Formerly too many of the acute appendicitis cases were operated upon too quickly after admission. There was no regard to dehydration, depleted protein, chlorides, and glucose. We do not hesitate to delay operation for three or four hours where it is necessary to supply fluid, plasma, or blood, and we believe that the better postoperative results justify the delay.

#### SUMMARY AND CONCLUSIONS

Sulfanilamide has been used locally in 320 out of a total of 739 cases of acute appendicitis and its complications during the past five years. The mortality in this group of cases was 0.4 per cent. The postoperative complications were relatively few.

In a similar group of cases in the five-year period before the use of local sulfanilamide, 742 cases were operated upon, with a mortality of 2.83 per cent and there were considerably more complications.

No serious toxic effects followed the use of sulfanilamide locally in the peritoneal cavity.

Local use of sulfanilamide is preferred to the use of sulfonamides orally or intravenously, because of the high local concentrations of the drug in the peritoneal cavity.

Cases complicated by abscess or peritonitis are given penicillin postoperatively in addition to the local use of sulfanilamide.

More frequent use of the McBurney incision is advised. All doubtful cases should be drained as they were before the use of the sulfonamide drugs.

The necessity of delay in operation in those cases having diminished body fluids and disturbed chemical equilibrium, until some correction of these conditions can be made. Delay should not exceed three or four hours.

More frequent use of local anesthesia is recommended for the critical peritonitis case, especially when simple drainage is the operation of choice.

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## SECONDARY HEMORRHAGE ARISING FROM GUNSHOT WOUNDS OF THE PERIPHERAL BLOOD VESSELS\*

MAJOR NORMAN E. FREEMAN, M.C., U.S.A.

SECONDARY HEMORRHAGE following gunshot wounds was formerly a common complication. In a series of 10,000 patients with wounds involving the long bones during the last war, Waugh<sup>1</sup> reported an incidence of 14 per cent secondary hemorrhage during the first year and 9 per cent during the second. Although present-day methods of débridement, immobilization and chemotherapy have resulted in a striking reduction in the frequency of this complication, the occasional occurrence of severe bleeding, often with disastrous consequences, still makes this problem an important one.

The following case is illustrative of what may result from an unrecognized injury of a major blood vessel:

**Case 1.**—The patient, age 27, a Chinese soldier, was struck just below the left shoulder by a .25-caliber bullet on March 1, 1944. The wound of entrance was over the lateral surface of the left arm below the acromium. He suffered a compound fracture of the humerus. The bullet lodged in the soft tissues of the axilla. Débridement of the wound had been performed in the forward area, and a plaster encasement had been applied to the left shoulder with the arm in abduction. At the time of admission he was moderately anemic, Hb. 8.8 Gm. It was noted that the radial pulse was normal. There was no swelling of the hand. Sensation and motion of the fingers were present. During the first week after admission he ran no fever. On March 14, two weeks after injury, the original encasement was changed. The wound appeared clean. A hanging plaster encasement was applied to the forearm and arm for traction and, in addition, a separate spica to cover the wound. On March 17, at 0700 hours, he was seen by the Officer of the Day who noted on the patient's record: "While brushing teeth a few minutes ago, patient must have opened wound. Began to bleed under encasement. It is now stopped and condition is good. Will probably need a new encasement."

At 1000 hours, the Ward Officer noted: "No further bleeding. General condition satisfactory. The wound can be seen underneath the encasement and is dry now." That afternoon, at 1330 hours, he again bled, vomited and fainted, even though the loss of blood was small. The Ward Officer removed the encasement, but the wound was then dry. On making inquiries the corpsman stated that he had seen the patient "picking at his wound with chop sticks," and it was thought that this action had caused some bleeding from the granulations.

For the next ten days there was no further bleeding and, although he now was running a little fever, the patient's course was, in the main, uneventful. The alignment of the fracture was satisfactory.

On March 27, almost four weeks after his original injury, at 0240 hours, the patient suddenly screamed. The corpsman found him sitting up in bed in a pool of blood. While his encasement was being cut off and efforts were being made to start a transfusion the patient died.

**Incidence.**—During the past year secondary hemorrhage from peripheral blood vessels has taken place in only 23 cases out of a total of 2,168 patients with gunshot or shell wounds of the extremities and neck cared for in this

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Army General Hospital.\* In eight of these cases the bleeding was from small vessels and was readily controlled by packing or by simple ligation of the bleeding vessel in the wound. In the remaining 15 patients, the hemorrhage resulted from the injury of a major blood vessel. It has been my privilege to examine 14 of these patients either before or after the bleeding and to operate upon 12 of them. It is on the basis of the findings in these cases that this study is made. It is hoped that by such an analysis wounds of major blood vessels may be recognized sufficiently early so that secondary hemorrhage may be avoided.

*Diagnosis.*—The location of the wound in every case of secondary hemorrhage was in the immediate proximity of the vessel involved. The position of the wound and the probable course of the missile should, therefore, suggest the possibility of vascular injury. In a series of 1,162 cases of secondary hemorrhage, Waugh<sup>1</sup> found that 68 per cent were associated with compound fractures. A similar frequency was found in our patients. Yudin,<sup>2</sup> in a recent series of 500 cases of compound fractures of the femur, reported that delayed hemorrhage was responsible for death in 1.6 per cent. In Table I is shown the location of the vessel responsible for the hemorrhage in this series.

The second finding of importance was the history of bleeding after injury. In two-thirds of the cases there was either a clear story of massive hemorrhage, or recurrent bleeding while in the forward area, or of severe anemia at the time of admission. Such loss of blood should make one suspect the injury of a large vessel.

Physical examination at the time of admission was not helpful. In spite of proven large lacerations of major arteries, the peripheral pulses were described as normal in six cases, diminished in two, and absent in only two patients. Of more significance was the presence of peripheral edema and a sense of numbness of the distal parts of the extremity. One or the other of these signs was present in the majority of patients. Tissue damage from severe ischemia was present in the hands of two patients, even though at the time of admission the fingers were warm and the radial pulses were palpable. Such edema of the intrinsic muscles of the hand could only have been caused by severe ischemia of long duration. Since the circulation was adequate at the time of admission, this finding pointed to a severe arterial injury for which compensation had been provided either by resumption of blood flow through the injured vessel or by the development of collateral circulation.

An hematoma about the injured vessel was present in four cases, although a systolic bruit was audible in but two of these. On the contrary, no bruit was audible in four other patients, even on careful examination with the possibility of an arterial lesion in mind. Gage<sup>3</sup> has stated that "sometimes the murmur does not manifest itself for hours or even days following vascular injury."

The interval of time between wounding and secondary hemorrhage was

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\* Twentieth General Hospital, Assam, India.

quite variable. During World War I,<sup>1</sup> bleeding most frequently occurred between the 10th and 16th day. Our earliest case bled on the second day while the longest interval was three months. Two-thirds of the patients bled within the first two weeks.

In going over our cases, we were chagrined to find that in seven of the cases, as in the patient whose clinical history is given above, one or more episodes of bleeding occurred before the hemorrhage which prompted operation. Failure to heed this "red signal" was responsible for death in only this instance, but in several other cases it was only the prompt intervention of skilled ward personnel which prevented a fatal outcome. As emphasized by Waugh,<sup>1</sup> "a small initial hemorrhage occurs in more than half the total cases and constitutes an inexorable indication for exploration of the wound. The nursing staff must be instructed to report even a slight hemorrhage or the discharge of small clots at once. Often, should this warning be disregarded, within a few hours there is a greater, maybe a life-endangering, loss." He goes on to comment on the constitutional reaction to the premonitory leak, which is sometimes out of all proportion to the amount of blood lost. This observation was dramatically confirmed in the first case here reported. In the majority of the patients the hemorrhage occurred spontaneously but in several there was a reasonable explanation which lulled us into a false sense of security. Mention has been made of "brushing the teeth" and "picking at the wound." Sudden movements—getting off the bed pan, falling to the floor and even refracture of the femur, could not serve as a reasonable excuse for the bleeding since in each case exploration, after a second hemorrhage, disclosed the laceration in the artery.

Since almost all compound fractures are now evacuated to the rear in plaster encasements, and since many are subsequently treated by plaster fixation, the question arose as to whether encasement of the wound in plaster contributed to the difficulty in treatment of the secondary hemorrhage. In three cases the patients bled into their encasements, and there is no doubt but that the presence of the encasement hindered early diagnosis and treatment. The incidence of bleeding is so small and the advantages of plaster fixation so well established that the added risk seems to be of little significance. But all the more emphasis should be placed on a search for signs of involvement of the major blood vessels before the encasement is applied.

*Management.*—Once the hemorrhage has occurred, immediate arrest of the bleeding is imperative. Packing of the wound with dry gauze and the application of pressure has generally been sufficient. Digital compression of the artery above the bleeding point may be necessary. A tourniquet about the limb should be used only as a last resort because of the damage to the peripheral tissues. Finally, especially in small wounds of the neck, digital compression of the bleeding point may be the only method which will suffice.

As soon as the bleeding has been arrested the blood lost should be replaced by transfusion, and arrangements should be made for immediate exploration of the wound. A long incision for adequate exposure is essential since the

circulation through the afferent artery must be controlled before the bleeding point can be found. We have not hesitated to open and extend the original wound. Proximal ligation through a separate wound has been performed only once, and this was for recurrent bleeding after a previous ligation of the femoral artery. After adequate exposure, rubber tubes are then placed about the artery both proximally and distally to control the bleeding. After this procedure, the bleeding point can be sought in a dry field without the danger of injury to accompanying nerves or other important structures.



*U. S. Army Medical Museum A44719*

FIG. 1.—Ruptured false aneurysm of popliteal artery. Femoral artery controlled with rubber tubing.

Figure 1 illustrates the control of the femoral artery in the adductor canal, with exposure of a ruptured false aneurysm.

It has long been recognized that laceration of a large vessel is more likely to lead immediately to severe bleeding than is complete severance, since in the latter case the hemorrhage is in part controlled by retraction of the two ends of the vessel. It was, therefore, not surprising to note that in every case but one in our series, a lacerated vessel was responsible for the bleeding; and even in that instance, recurrent hemorrhage which required a second operation took place from a partially divided vessel. Sir George Makins, according to Waugh,<sup>1</sup> believed that "an incomplete lesion of a blood vessel preëxists in every case of secondary hemorrhage."

At the time of operation, considerable difficulty may be encountered in

finding the laceration in the artery. The bleeding has presumably already been arrested on the ward by the preliminary packing and pressure. The patient's circulation is probably depressed from the loss of blood. The laceration in the vessel has again been sealed by a clot. In five of our cases, even after wide exposure, the point of bleeding was not at first apparent. With gentle manipulation, however, especially when the arterial pressure was raised by transfusion of blood, the actual source of the hemorrhage was revealed by a gush of blood. A large laceration in a major vessel has been responsible for the bleeding in all our cases. In one patient, when we thought that a small branch of the main artery was responsible for the bleeding, a second hemorrhage after transfusion forced us again to explore the wound. Large laceration of the popliteal artery was then found. In no case has it been necessary to pack the wound. This procedure has been recommended,<sup>1</sup> with subsequent removal of the packing in the operating theater 48 hours later, in those cases in which the site of the bleeding cannot be found.

*Neck Wounds.*—Severe hemorrhage from a large vein, presumably the internal jugular vein, was encountered but once.

**Case 2.**—The patient, a Chinese soldier, age 26, was struck on June 2 by grenade fragments over the midpoint of the right sternomastoid muscle. The fragments lodged in the body of the third cervical vertebra. Débridement of the wound was performed in the forward area. Although no operative notes accompanied the patient the fact that the wound had been packed suggested that severe bleeding had occurred. There was little swelling of the neck but the patient was hoarse and had a Horner's syndrome on the right side. Five days after injury, removal of the packing on the ward was followed by a brisk gush of venous blood. The bleeding was controlled by repacking the wound. He was taken to the operating room, local anesthesia was injected into the margins of the wound and the packing again removed. The resultant hemorrhage was definitely venous in character, and was readily controlled by digital pressure in the wound. Since the induration of the tissues and the site of the wound made exposure of the internal jugular vein hazardous it was decided to control the bleeding by suture of the wound. Five silkworm-gut sutures were placed through the skin and deeper tissues. As the middle one was tied the finger was removed from the depths of the wound. No further bleeding occurred. The patient was kept in a sitting position for one week. The wound healed well. Examination of the eyegrounds showed no venous engorgement. After healing was complete there was no bruit audible over the right side of the neck.

There were two additional patients who developed secondary hemorrhage from neck wounds.

**Case 3.**—A Chinese soldier sustained a shell fragment wound just below the angle of the mandible on the left side on March 18, 1944. The fragment lodged in the transverse process of the first cervical vertebra. Débridement was performed in the forward area. The note which accompanied the patient stated that "much bleeding" was encountered. He was admitted to the hospital the following day. Three days later swelling was noted below the mandible on the left side. This swelling increased in size and the patient complained of severe pain. His temperature was normal. On March 30, 12 days after his injury, with the preoperative diagnosis of cervical abscess, the mass was incised. A "rush of blood" occurred, which was controlled with difficulty by suture of the skin and a pressure dressing. On April 7 a pulsating tumor, with a palpable thrill and a continuous murmur, was present below the lobe of the left ear. The wound was

healing but there was serous fluid weeping from the skin edges. The anterior jugular vein was distended when the patient lay down but was collapsed when he sat up. The pulse rate dropped from 72 to 60 on pressure over the carotid artery sufficient to abolish the murmur. A diagnosis of arteriovenous aneurysm was made. Hemorrhage from an arteriovenous aneurysm is rare because of the free communication with the venous side of the circulation and the resultant low pressure within the aneurysmal sac. In this particular case it was considered desirable, if possible, to allow complete healing to take place before excising the fistula and, accordingly, a tight bandage was applied. In retrospect, this procedure was probably a mistake since compression of the tissues would, if anything, raise the pressure in the aneurysm through pressure on the venous outlet. The following morning, at 0530 hours, the patient cried out and the nurse found him sitting up in bed with blood streaming from his neck. She controlled the bleeding by digital pressure. The patient was taken to the operating room and, under local anesthesia, the external carotid artery was exposed below the digastricus. The circulation was temporarily occluded by a rubber tube. The arteriovenous aneurysm was then opened and excised with quadruple ligation of the component arteries and veins. It had originated from the external maxillary artery and the temperomaxillary vein.

COMMENT: This case emphasizes the importance of considering the possibility of aneurysm before incision of a mass in the neck, especially following gunshot wounds in this region. Also, it would have been wiser to have excised the aneurysm as soon as the diagnosis was made in this case. Only the prompt action of the nurse in attendance prevented this patient's death.

A second fatality in this series occurred from a wound of the carotid artery.

Case 4.—A Chinese soldier, age 24, was struck by a shell fragment on June 5. The missile entered the right side of the neck through the upper third of the sternomastoid muscle and lodged against the fifth cervical vertebra. He was admitted four days after injury. His voice was hoarse and he had a Horner's syndrome on the right side. Examination of the throat revealed paralysis of the right vocal cord and an old submucosal hemorrhage on the right side of the posterior wall of the pharynx. There was induration of the neck but no pulsation, bruit or thrill. The wound of entrance was clean. Roentgenologic examination, 11 days after injury, revealed deviation of the trachea to the left and a swelling of the retropharyngeal tissues. His course in the hospital was quite uneventful. He was ambulatory and his wound was almost healed. On July 2, four weeks after injury, he was found by the corpsman, at 2330 hours, lying on the floor in a pool of blood. He died in a few minutes.

COMMENT: In spite of the absence of pulsation, thrill or bruit, this patient probably had an extensive laceration of the carotid artery. Clearly, exploration should have been performed. The associated injuries to the vagus and cervical sympathetic nerves, together with the presence of a mass in the neck and roentgenologic evidence of retropharyngeal swelling and deviation of the trachea to the opposite side, should have been sufficient indication that arterial hemorrhage had occurred.

*Gas Gangrene.*—Gas gangrene was present at the time of operation in two cases.

Case 5.—An American soldier was wounded through the right thigh by a .30-caliber bullet on July 11. He sustained a compound fracture of the femur at the junction of the distal and middle thirds. Débridement of the wound and plaster fixation were not possible until 22 hours after injury. He was admitted to the hospital four hours later. At that time, he was disoriented, his temperature 103° F., and pulse 130. The toes were

warm, though edematous. Sensation was normal. The following afternoon, at 1530 hours, because of the swelling of the toes, the encasement was split. An hour later, while he was receiving a transfusion, he suddenly had a large hemorrhage. The encasement was rapidly opened and the bleeding controlled by packing. He was operated upon at 1745 hours. The posteromedial wound just above the popliteal space was explored, the femoral artery isolated and controlled in the lower part of the adductor canal. A small branch of the femoral and second small laceration in the arterial wall were thought to be responsible for the bleeding. The patient's condition was poor. He was given 1000 cc. of blood during the operation. After the dressings were applied and a Kirschner wire inserted through the tibia a second severe hemorrhage occurred. Reexploration of the posterior wound now disclosed a large laceration in the popliteal artery. The artery was ligated and divided.

After recovery from shock, at 2000 hours, ischemia of the leg was marked and crepitation was present in the muscles on the lateral side of the leg just below the knee. The leg was amputated through the fracture site, under local anesthesia. His temperature and pulse kept rising, he became stuporous, and died four hours after operation. Culture from the wound revealed both *Cl. welchii* and *Cl. sordelli*.

COMMENT: Earlier recognition of the gas gangrene with immediate amputation at a higher level might have saved this patient's life.

Case 6.—A Chinese soldier, age 24, was wounded by a shell fragment in the right arm on March 2. The missile entered the anteromesial surface of the upper arm. The wound of exit was on the anterolateral surface at the same level. At the time of admission on March 3, his hemoglobin was only 8.0 Gm. The right arm was swollen, but the radial pulse was good. A few gas bubbles were present in the wound, but there was no crepitation in the tissues. Two days later the swelling had increased. On the fifth day after injury a moderately severe hemorrhage occurred, which was thought to be venous in character. The drain was removed since it was pressing on the brachial artery. Since it was felt that the bleeding had occurred from excessive movement, an abduction encasement was applied to the right arm. The left shoulder was incorporated in the encasement, but the injured right shoulder was left covered simply by a dressing. The following night, March 8, the patient fell from the bed pan to the floor, broke the encasement, and was found by the Officer of the Day lying in a pool of blood. The corpsman stated that the patient had been slightly irrational for some days but since he had also suffered head trauma it was to this injury that his mental confusion was attributed. Hemorrhage, clearly arterial in nature, recurred the next afternoon. The pulse at the wrist which had previously been present was now gone. In the operating room the axillary artery was first controlled and the brachial then exposed. It was found to be halfway cut in two at the junction of the upper and middle thirds of the arm. It was divided and ligated. By the following morning gas gangrene was present. Amputation through the upper third of the arm was followed by recovery.

*Ischemic Gangrene.*—In addition to the two cases of gas gangrene in which amputation of the extremity was performed, a third patient developed gangrene requiring amputation after ligation of the femoral artery just above the popliteal space.

Case 7.—This patient had been wounded by a shell fragment on July 11. The missile traversed the left thigh, causing a supracondylar fracture of the femur. The original bleeding had not been severe. He was admitted on July 12. On examination, the left foot was warm and the dorsalis pedis pulse was palpable. His wound became infected and he ran an intermittent fever. About four weeks after injury, pitting edema of the foot was noted. On September 15, two months after injury, bleeding took place



from the posterolateral wound. It amounted only to about 100 cc. of serosanguineous material, although some small clots were present. This hemorrhage came on immediately after use of the bed pan. Distortion of the thigh was noted. Roentgenologic examination confirmed the clinical impression of displacement at the fracture site, even though his leg had been in skeletal traction at the time. When I examined him the ankle pulses were normal, motion and sensation of the toes were present, and there was no pulsation, thrill or bruit over the femoral vessels just above the knee. One week later, an accumulation of pus on the posterolateral aspect of the lower thigh was drained. He continued to show a slight amount of blood on his dressings. The medial wound by this time was almost healed. On October 8, nearly three months after his original injury, a brisk hemorrhage occurred from the posterolateral wound. The bleeding was controlled by packing. Under spinal anesthesia, the femoral artery was exposed in the adductor canal and, after controlling the circulation, the site of the bleeding was sought. It proved to be a ruptured false aneurysm (Fig. 1). Release of the distal end of the artery allowed no "back-bleeding." It was felt that the collateral circulation was insufficient and, accordingly, the laceration in the femoral artery was sutured. No pulsation of the artery below the line of suture took place after release of the upper rubber tube. Marked ischemia of the tissues below the knee was present after operation. The lower leg was refrigerated for five days, but no improvement took place. Amputation through the fracture site was performed on October 14. Dissection of the arteries of the leg revealed that thrombosis had occurred below the point of suture.

**COMMENT:** In retrospect, it would have been better to have ligated and divided the artery at the time of operation. By such a procedure, progressive arterial thrombosis and spasm of the artery distal to the point of injury might have been prevented.

*Suture vs. Ligation.*—Suture of the laceration of the arterial wall was attempted only twice. It failed in the case cited above. It was successful in the second patient, whose brachial artery was found to have been lacerated when his wound was explored for secondary hemorrhage two weeks after his original injury. After suture of the arterial wall, pulsation of the artery distal to the injury was immediately apparent. Subsequent examination confirmed the patency of the artery. In all the remaining cases of bleeding from large arteries, the vessel was divided and ligated. The use of catgut for the ligation of major arteries had been condemned by Reid,<sup>4</sup> especially in the presence of wound infection, because of the likelihood of rapid disintegration of the absorbable suture material. In all of our cases No. 1 chromic catgut was used, without untoward results. The fact that the sepsis in the wounds was controlled by adequate drainage and the use of sulfonamides may have prevented subsequent weakening of the catgut or sloughing of the tissues of the vessels at the site of ligation before permanent occlusion had occurred.

*Paravertebral Alcohol Injection.*—Interruption of vasoconstrictor impulses by chemical section of the sympathetic nerves has been suggested by Gage and Ochsner<sup>5</sup> to prevent ischemic gangrene after surgical operations on major peripheral blood vessels. Following ligation of the main artery of the extremity, injection of alcohol into the region of the paravertebral sympathetic ganglia was performed in four of our cases. Repeated injections of procaine were made in an additional case. In the single instance, when the blood supply to the extremity was seriously curtailed, in which this procedure was

not employed, gangrene occurred. It is regretted that this patient was not given the benefit of prolonged vasodilatation after ligation of the femoral artery. Gangrene might have been prevented.

### SUMMARY AND CONCLUSIONS

The incidence of secondary hemorrhage in 2,168 cases of gunshot wounds of the neck and extremities was 1.06 per cent. Of the 23 patients, 15 bled from wounds of major blood vessels. The present study is based on an analysis of these 15 cases.

Laceration of the arterial wall, rather than complete severance, was found in the 13 cases whose wounds were explored. There were three deaths in the group. Two patients developed gas gangrene and one of these died. Ligation of the femoral artery resulted in ischemic gangrene requiring amputation in one case. Recovery took place in the remaining patients.

TABLE I  
SITE OF HEMORRHAGE IN 15 CASES

	No. of Cases
Neck:	
Internal jugular.....	1
Carotid.....	1
Arteriovenous aneurysm.....	1
Upper extremity:	
Axillary.....	2
Circumflex humeral.....	1
Brachial.....	4
Lower extremity:	
Femoral.....	4
Popliteal.....	1

A history of severe or recurrent hemorrhage in the forward area, or the presence of severe anemia on admission, is indicative of injury to a large blood vessel. Secondary hemorrhage is to be anticipated in this group. In spite of a demonstrated large opening in the main artery of the extremity, the peripheral pulse was normal in six cases, reduced in two, and absent in only two patients. Periarterial hematoma was found in four individuals, but pulsation and bruit was present in only two of these. Peripheral edema or diminished sensation in the distal parts of the extremities was present in three-quarters of the cases with lacerations of the blood vessels of the extremities.

One case is reported of the rupture of an arteriovenous aneurysm of the neck. In a second case of secondary hemorrhage from the neck, the bleeding, which was definitely venous in origin, was controlled by suture of the tissues over the bleeding point. Both cases recovered.

In all patients the major artery was exposed by wide extension of the original wound. Suture of the arterial laceration was attempted on two occasions. It was apparently successful in one case. In the second case thrombosis at the suture line extended downward and contributed to the development of gangrene. In the remaining patients the artery was divided and

ligated with No. 1 chromic catgut. No untoward results were observed after the use of this absorbable suture material.

Injection of alcohol into the region of the paravertebral sympathetic ganglia was performed in four cases, with good results. In a fifth patient, procaine was repeatedly injected.

A small initial hemorrhage occurred in seven patients before the severe blood loss which prompted operation. Attention is again<sup>1</sup> called to this "red signal" as an "inexorable indication for exploration of the wound."

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# SECONDARY INFECTION OF WOUNDS\*

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SECONDARY INFECTION following the original infection of an open wound is so commonplace as to pass unnoticed. The average surgeon accepts it as a matter of course and unless the patient's life is endangered or his leg about to require immediate amputation, he thinks nothing need be done to improve the situation. Actually, secondary wound infection is the principal cause of delayed healing and impaired function. Moreover, such infections are to a great extent preventable, and even established infections can frequently be eliminated.

Primary wound infections (to distinguish them from the secondary) are those caused by bacterial contamination at the time of injury. These bacteria are derived from soil, clothing, skin and foreign bodies. The organisms existing in soil usually belong to the fecal group (*Entero-bacilli* and *Clostridia*) or, as Meleney has classified them, pathogenic aerobic gram-negative bacilli and *Clostridium welchii*. Those found in the skin and clothing are *hemolytic Streptococcus* and coagulase-positive *Staphylococcus aureus*. Hematogenous osteomyelitis, which is usually produced by the *Staphylococcus aureus*, remains an uncomplicated infection until drainage has been established and other organisms have gained access to the wound. Thereafter, the problem is to obtain healing of a wound in which there is established, mixed infection.

Secondary infections are those caused by bacteria introduced into the wound at any time after the initial injury. These invaders may come from the skin of anyone touching the wound, from unsterile instruments or dressings or from the respiratory tract of the patient or of his attendants. They may fall into the wound with dust from the floor of a ward and may be drawn by capillary attraction through a soggy dressing which is in contact with soiled linen.

The organisms, thus acquired, usually consist of *hemolytic Streptococci* and *Staphylococci* and *Bacillus pyocyaneus*. In a recent editorial in *Lancet*, it was reported that a survey revealed these organisms to be present in only 5 per cent of fresh wounds upon admission to the hospital, but after a week in the institution 50 per cent of the wounds contained secondary invaders and later on they were found in 70 to 80 per cent of the open wounds. Altmeier,<sup>1</sup> at the Cincinnati General Hospital, found that contamination of fresh accidental wounds with *hemolytic Staphylococcus aureus* had already occurred in 35 per cent of the cases by the time débridement was done, the

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organisms having been introduced probably during the administration of first-aid or during transportation, early examination and observation prior to operation. With regard to other organisms Altmeier adds: "In previous wars as well as in time of peace the spread of *P. aeruginosa* through a crowded hospital surgical ward was well known and was easily recognized by the green or greenish-blue discoloration of the dressing. This phenomenon is of great importance since it is a visible indication of flaws in surgical technic and it would be probably easier to establish growth of a greater pathogen than *P. aeruginosa* such as the *hemolytic Streptococcus* or the *hemolytic Staphylococcus*."

TABLE I

## SOFT-PART WOUNDS

Incidence of Pathogenic Aerobic Gram-negative Bacilli and *Cl. welchii* in Débrided Tissue—Persistence—Later Appearance in Cases When Not Originally Found\*

	Pathogenic Aerobic Gram-negative Bacilli			<i>Clostridium Welchii</i>		
	Débrided Tissue	Persisting	New	Débrided Tissue	Persisting	New
Total.....	147	26	33	138	12	9
Serious infections.....	21	11	8	13	4	3
Trivial infections.....	20	8	19	19	3	4

\* From subcommittee on Surgical Infections and Burns, National Research Council.

TABLE II

## SOFT-PART WOUNDS

Incidence of *H. Strep.* and Coag.-pos. *Staph. Aureus* in Débrided Tissue—Persistence—Later Appearance in Cases When Not Originally Found\*

	<i>Hemolytic Streptococcus</i>			Coagulase-positive <i>Staphylococcus Aureus</i> †		
	Débrided Tissue	Persisting	New	Débrided Tissue	Persisting	New
Total.....	55	11	18	74	16	51
Serious infections.....	9	4	6	7	3	14
Trivial infections.....	13	5	6	14	10	27

\* From Subcommittee on Surgical Infections and Burns, National Research Council.

† This does not include other coag.-pos. micrococci.

Further evidence that secondary wound infections are both frequent and serious is included in the report of the studies made by the Committee on Infected Wounds and Burns of the National Research Council.<sup>2</sup> The débrided tissues from contaminated soft part wounds and compound fractures were cultured and later cultures were taken from the unhealed wounds from time to time. The following tables (Tables I–IV) taken from parts of the report show the number of cases in which the various organisms identified in the débrided tissues persisted and, in addition, the number in which the various bacteria appeared as new. In both categories the resultant infections are rated as trivial or serious.

Approximately two-thirds of the soft-part wounds and one-third of the compound fractures healed without appreciable infection. Further analysis

# SECONDARY INFECTION OF WOUNDS

of these figures reveals that of 414 cultures of débrided tissue from soft-part wounds some one of the four groups of pathogens persisted in 45 instances, but they appeared as "new" in 87 cases. In 362 compound fractures the same organism appeared as "persistent" in 73 cases but as "new" in 166. Dr. Meleney, who compiled the report, expressed the opinion that some of the bacteria which appeared as "new" in subsequent wound cultures represented multiplication of organisms remaining in the wound at the time of débridement but too few in number to propagate and be identified from

TABLE III

## COMPOUND FRACTURES

Incidence of *H. Strep.*, and Coag.-pos. *Staph. Aureus* in Débrided Tissue—Persistence—Later Appearance in Cases When Not Originally Found\*

	<i>Hemolytic Streptococcus</i>			<i>Coagulase-positive Staphylococcus Aureus</i> †		
	Débrided Tissue	Per- sisting	New	Débrided Tissue	Per- sisting	New
Total.....	50	13	32	54	19	55
Serious infections.....	12	8	16	8	7	31
Trivial infections.....	13	2	8	9	7	11

\* From Subcommittee on Surgical Infections and Burns, National Research Council.

† Does not include other coag.-pos micrococci.

TABLE IV

## COMPOUND FRACTURES

Incidence of Pathogenic Aerobic Gram-negative Bacilli and *Cl. welchii* in Débrided Tissue—Persistence—Later Appearance in Cases When Not Originally Found\*

	<i>Pathogenic Aerobic Gram-negative Bacilli</i>			<i>Clostridium Welchii</i>		
	Débrided Tissue	Per- sisting	New	Débrided Tissue	Per- sisting	New
Total.....	111	20	55	147	21	14
Serious infections.....	28	13	17	38	12	5
Trivial infections.....	11	4	31	17	2	4

\* From Subcommittee on Surgical Infections and Burns, National Research Council.

the débrided tissues. It seems reasonable, however, that the majority of the bacteria appearing as "new" in subsequent wound cultures were secondary invaders. It is noteworthy that these four groups of pathogens appeared as new or secondary invaders twice as often as they persisted. It is significant also that the resultant infections are rated as serious in a little less than half the soft-part wounds with "new" invaders and considerably more than half of the same group under compound fractures.

From a study of this report the following deductions may be made:

(1) Pathogenic organisms can be eliminated in most cases by the body's defense mechanisms when these are aided by adequate surgical débridement.

(2) Pathogenic organisms persist as serious or trivial infections in 10 to 25 per cent of cases.

(3) They appear as new invaders and produce serious and trivial infections in 20 to 50 per cent of cases.

(4) Of the serious persistent infections developing in wounds, probably at least half are caused by bacteria secondarily introduced.

In view of these facts, the "*laissez faire*" attitude of surgeons toward secondary wound infections is not justifiable. Surgeons are correct in placing major emphasis upon the general condition of the patient and adequate drainage but are incorrect when they ignore the changing bacterial flora in the wound under treatment.

#### DIAGNOSIS

From the viewpoint of treatment, any wound not making reasonable progress toward healing from day to day may be considered as secondarily infected. The indications for the procedures necessary in treatment differ in the early and late stages. Such factors as slough, deep pockets, inadequate blood supply, scar tissue, foreign bodies, cavitation and sequestra in the bone undoubtedly predispose to propagation of the organisms principally responsible for persisting infections, and these can be judged from the gross appearance of the wound from roentgenograms of the bone. Identification of the bacterial flora, especially when gram-negative organisms predominate, is of definite assistance in selecting specific agents for systemic or local treatment. The clinical picture and bacteriologic flora differ greatly, however, in the early stage of wound healing at the end of from five to ten days and in the latter stages, after two to six months.

In the early stages, fever, edema and redness about the wound, the character and quantity of exudate intermingled with blood clots, presence of sloughing tissue or ecchymotic swollen muscle ends and absence of granulation tissue suggest incomplete débridement and the presence of pabulum favorable to the growth of anaerobes and gram-negative organisms. Smears and cultures taken from pockets in the wound will usually show numerous colonies of *B. pyocyaneus*, *E. Coli* and *Clostridia welchii*, together with staphylococci and streptococci.

Wounds in the later stages may not be accompanied by fever, localized swelling or redness, but the margins may have formed a scar, the granulations may be pale, edematous or sloughing, and there is apt to be a sinus leading to a cavity in the soft-parts or bone. Cultured material will usually reveal a mixture of organisms with predominance of the gram-negative type.

#### TREATMENT

Treatment should begin at the time of injury with preventive measures. The plan of management for the early and late stages will vary somewhat with the local condition of the wound and the bacterial flora discovered in the cultures.

*Preventive Treatment.*—Prevention of secondary infection and consequent delayed healing must begin with proper control of the primary infection;

hence, it must start with first-aid measures. Instead of the small, thin dressing, usually applied with strips of adhesive tape and a few turns of bandage, it would certainly be more ideal if the wounds could be covered with a massive sterile dressing, applied with pressure by masked attendants familiar with sterile technic, covered with sterile, impermeable material and immobilized in a splint for transportation. Except in cases of critical hemorrhage, this dressing should not be removed until the patient is in an operating room and can be prepared for débridement. Sedation and measures to combat shock, fluid loss and blood deficiencies should be instituted promptly. Tetanus antitoxin or "booster" doses of the toxoid should be given as indicated. Roentgenograms should be made while these are under way in most cases, but extreme care should be taken to move the patient as little as possible. Hospital efficiency should make possible performance of débridement within three hours of the time of injury.

The technic of débridement will not be described in detail since it is generally well understood. Cleansing of the skin should be meticulous, the exposure wide and removal of devitalized tissue and foreign bodies thorough. In civil practice, closure of well selected cases is most desirable, but when doubt of its advisability exists, when closure can be accomplished only with tension and when tissue damage and gross contamination are coupled with an interval of more than six hours between injury and débridement, the wound should not be sutured. Local application of bacteriostatic agents after débridement probably has no real value. Systemic administration of one of the sulfa drugs or penicillin should be started immediately after operation.

The patient's general condition should receive close attention for the next week. Adequate food, blood, fluids and penicillin should be administered. Wounds that have been closed should require no further dressing until they have healed. If the wound has been left open, it should be secondarily closed from five to ten days after operation depending upon progress of the case.

Secondary closure is an operative procedure to be undertaken in the operating room. Removal of the plaster and dressing, immobilization of the extremity and preparation of the wound and surrounding skin should be carried out as was originally done for débridement. If the appearance of the wound and the discharge indicate it, a second débridement should be done and the wound again left open, dressed and immobilized. If, however, the wound is healthy, the skin edges may be undercut a little way, the muscles drawn together and the skin approximated with interrupted sutures without tension. A massive pressure dressing, an impermeable layer and a plaster encasement should then be reapplied. This dressing can usually be retained until healing occurs. If it becomes necessary to provide drainage because of fever and abscess formation, the same procedure should be carried out again in the operating room with due care to prevent secondary invasion of the wound by new bacteria. Not until the wound has been reduced to a reasonable size, with small draining sinus, should dressings be done in the ward or room through a windowed plaster.



*Dressing Technic.*—In view of the origin of bacteria that become secondary invaders of wounds, it is essential to revise the dressing technic usually employed. It would be ideal to have two or three rooms reserved for this purpose and to have a special team of physicians, nurses and attendants. Patients should be moved to these rooms for dressing. Special precautions against dust-borne organisms should be observed, such as ventilation, oiled floors and bactericidal lights. In one room plasters should be cut and dressings removed and immediately discarded. The patient should then be wheeled into a second room set up as an operating room where the skin should be cleansed and draped under bactericidal lamps, the wound treated and a massive dressing applied. Final bandaging and reapplication of splints should be performed in a third room. Although such a set-up would be expensive to maintain, in a private hospital it could be made self-supporting and even profitable by charges of \$15 to \$25 for each dressing. Work should be scheduled for the surgeons as in the operating room. Cost would be minimized by the infrequency of dressings and the shortened period of hospitalization and disability. The use of dressing trays and carts would then be reserved for removal of stitches from clean wounds and the dressing of small surface granulating areas.

*Treatment of Early Stages.*—When the wound is dressed from five to ten days postoperatively, if active infection is evident as indicated by the gross appearance of, or by the cultures from, the wound, or both, secondary débridement and better drainage is indicated. Bacteriostatic agents given systemically should be continued. Secondary closure cannot be considered until the wound surfaces present a healthy appearance and sloughs have disappeared. Dressings for observation should be done infrequently and with the aseptic technic previously described.

*Treatment of Late Stage (Chronic Osteomyelitis).*—Chronic localized osteomyelitis is the end-result of mixed infection in bone and soft tissue caused by repeated secondary infection. Treatment must be directed first toward the patient and his body defenses. Often, the first step toward this end is to provide adequate drainage of an abscess by a short operative procedure. Adequate local preparation and absolute protection against further secondary infection must be provided from the outset. Careful inventory of the patient's defense resources should then be taken and the deficiencies made up by food, vitamins, tonics, sunshine and exercise. The condition of the bone and soft parts should be thoughtfully evaluated and an operative plan formulated. If the general condition of the patient has been sufficiently restored in advance, it should be further fortified by penicillin therapy for from three to five days and repeated, careful skin cleansings and dressings. Blood should be ready for transfusion during and after operation.

The operation accomplishes removal of all scar tissue and sufficient involucrum and bone not only to flatten cavity but to permit soft-parts to fall together. The value of this step was shown by the work of Dickson, Diveley and Kiene.<sup>3</sup> Whenever possible the skin should be mobilized mod-

erately so that it will approximate easily at secondary closure. Regardless of the prospect of early skin coverage, the remaining bone should be covered by muscles, even when a muscle flap must be formed and slid into position. Many wounds with a single cavity or focus in portion of bone easily covered without tension can be closed primarily. The more extensive ones should be covered with vaselined gauze and left open, and, from seven to ten days

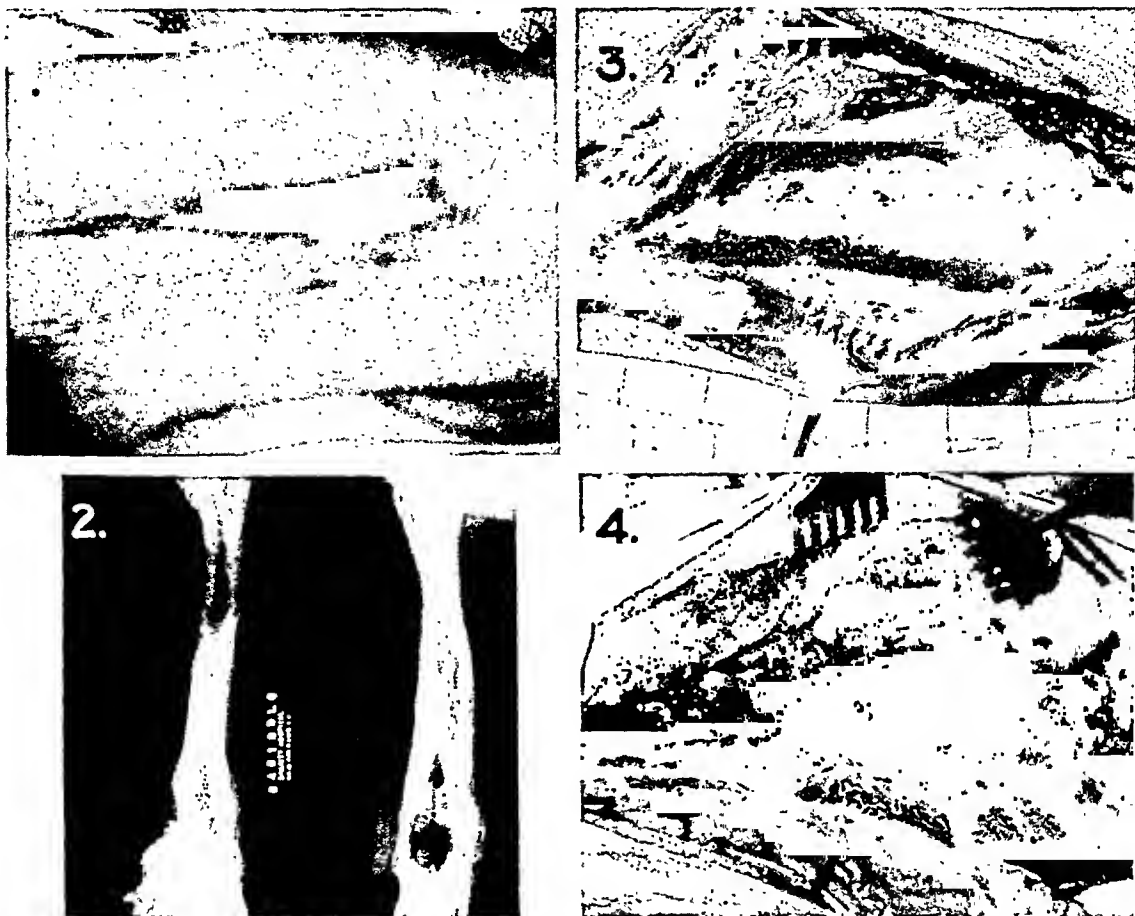


FIG. 1.—Chronic hematogenous osteomyelitis of the lower end of the femur, with established mixed infection.

(1) Lateral aspect of thigh with scar and sinus. (2) Roentgenogram showing extensive cavitation and sclerosed walls. (3) Exposure of bony cavity through lateral incision. (4) Bony cavity saucerized, biceps tendon detached and ready to be inserted into the cavity in the external condyle.

later, closed secondarily. Faultless dressing technic must be observed until the wound finally heals. Continuance of measures directed toward building body defenses is essential throughout treatment. Those with large scars and great muscular atrophy will require skin grafting as soon as the granulating bed becomes healthy.

Two case reports will suffice to illustrate the advantages of control of secondary infections by improved dressing and operative technic combined with administration of penicillin before and after operation.

#### ILLUSTRATIVE CASE REPORTS

Case 1.—Chronic hematogenous osteomyelitis, cavity in lower femur and condyles with ankylosis of the knee (Figs. 1 and 2).

A. A., white, male, age 35, was admitted to Charity Hospital in New Orleans on March 5, 1945.

In 1941 he had an attack of acute hematogenous osteomyelitis, with localization in the lower portion of the left femur. This was drained by a lateral incision, but the focus became chronic and has required repeated operations for drainage, sequestrectomy and saucerization. In spite of these, the process spread to involve both condyles of the femur, destroyed the knee joint and resulted in fibrous ankylosis of the knee in extension. For the past year the patient has been well enough to walk without support but with a stiff knee and a draining sinus on the outer side of his lower thigh.

On admission, physical examination revealed an active, healthy-looking man with



FIG. 2.—Obliteration of bony cavity with transplanted biceps and vastus lateralis.

(1) Biceps tendon and muscle have been inserted into the external condyle and the vastus lateralis folded over the transplanted biceps. (2) Skin closure without tension. (3) Postoperative roentgenogram two weeks later when skin wound had healed. Fracture of shaft of femur is shown.



no significant abnormalities other than a stiff knee and chronic osteomyelitis involving the lower half of the femur. There was a dense scar on the outer lower half of the thigh, 12 inches long, varying in width from one-half to two inches and firmly attached to the bone. Wound cultures yielded growth of *Staphylococcus aureus* and *Bacillus pyocyaneus*. A large cavity involving the lower third of the shaft and both femoral condyles could be seen in the roentgenograms. The surrounding bone was dense and sclerotic.

For seven days prior to operation, the patient received 15,000 units of penicillin every four hours and the thigh and leg were shaved and cleansed thoroughly on three successive days before operation.

*Operation.*—On March 13, 1945, the scar and sinus were excised down to the bone;

this left a large defect on the lateral aspect bound by the vastus externus anteriorly and the biceps posteriorly. The scar extended into the bony cavities and a central granulating cavity filled with pus was found lying in the condyles and extending into the popliteal space. All of this was removed and the bony cavity was saucerized by removal of nearly two-thirds of the circumference of the bone. Because the knee was stiff and the controlling muscles functionless, it was possible to detach the vastus lateralis from the quadriceps tendon and the biceps from the fibula and insert them into the bony cavity, thus completely filling the defect even in the condyles. The skin could then be approximated without tension and was closed without drainage. A pressure dressing and a

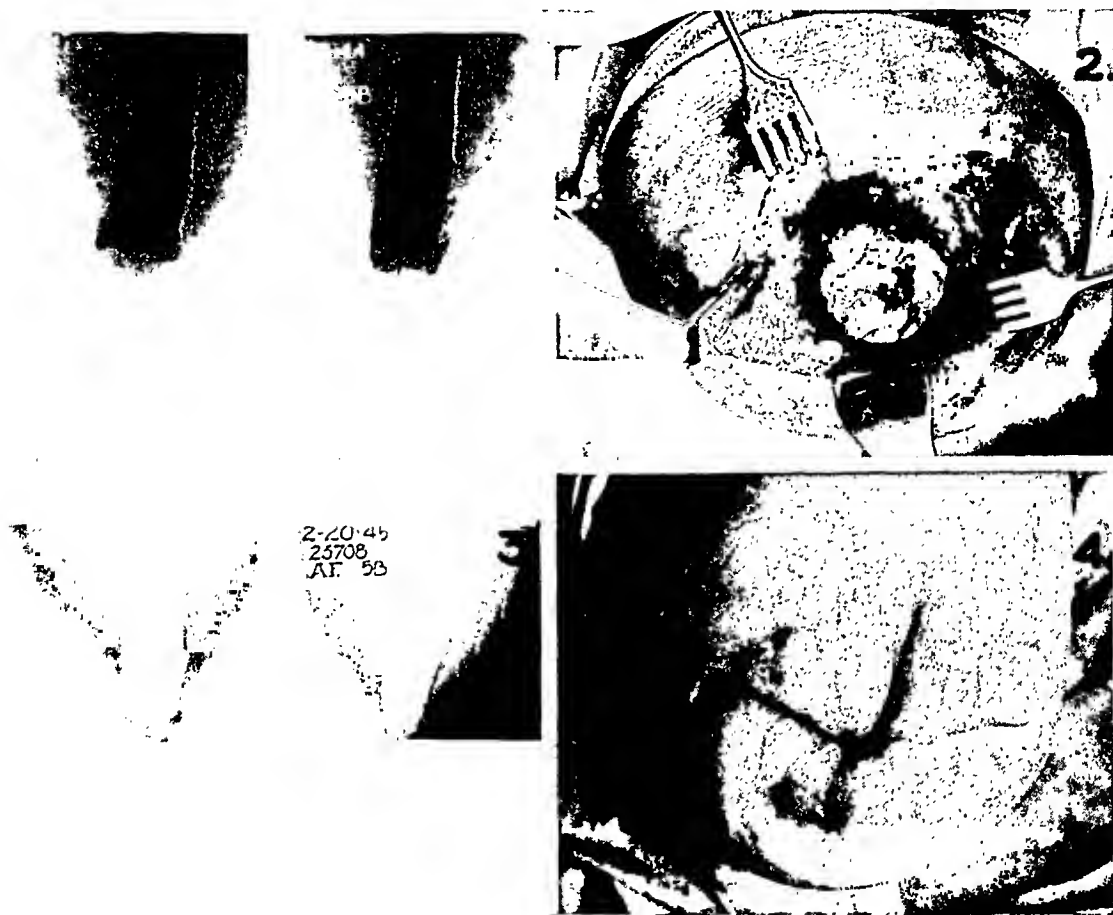


FIG. 3.—Chronic localized osteomyelitis of femoral stump.

(1) Preoperative roentgenogram showing cavitation and sequestration. (2) Scar removed exposing the end of the femoral shaft which is blocked with dense scar tissues. (3) Postoperative roentgenogram 12 weeks after operation. (4) Stump healed 12 weeks after operation.

long, leg plaster encasement were then applied. Five hundred cubic centimeters of blood were given during the operation and 15,000 units of penicillin were administered every four hours for two days. Sulfadiazine, 1 Gm. every four hours, was given for the next five days, and penicillin was again administered for the next two weeks. The systemic reaction to operation was mild, the wound healed primarily, the stitches were removed at the end of the second week, a plaster encasement was reapplied and the patient was dismissed to return in eight weeks. Postoperative roentgenograms showed a fracture, without displacement, in the upper part of the saucerized area.

COMMENT: Although the end-result in this case is problematic, the prompt healing of such a chronically infected, extensive cavity in bone can be attrib-

uted partly to the use of penicillin before and after operation, and partly to obliteration of the cavity with viable muscle.

**Case 2.**—Chronic localized osteomyelitis of the femoral stump (Fig. 3).

T. F., white, male, age 54, was first seen at the Ochsner Clinic, June 6, 1944, because of a chronic localized osteomyelitis in the amputated stump of his left leg. He had had an amputation through the middle third of the left femur two years before for thrombosis of the popliteal artery, which occurred as he was convalescing from pneumonia. The stump was sutured at the time of amputation, but infection developed and persisted with a draining sinus.

The patient, who appeared to be robust, was walking with the aid of crutches. Physical examination revealed generalized arteriosclerosis and heart disease. The end of the stump was edematous, the skin was glossy and mottled with purplish and brown discolorations, and there was a large granulating opening and profuse, shiny, yellowish discharge. The sinus led down to a sequestrum, seen in the roentgenograms as a large dense, cone-shaped plug at the distal end of the marrow cavity which was not entirely detached.

On July 5, 1944, the sequestrum was removed and the wound left open. At operation, it was not possible to remove all dead bone because sequestration was incomplete and the process was extending up into the marrow cavity. The wound closed gradually to a sinus, which persisted until December, 1944, when the patient was readmitted to the hospital. Cultures from the pus revealed *nonhemolytic Staphylococcus*. Penicillin was administered for one week preoperatively, and the stump was carefully cleansed and dressed.

**Operation.**—December 27, 1944: The scar was widely excised until healthy muscle was encountered. The fibrous plug covering the end of the bone extending up into the marrow cavity was then removed. A cavity in the bone one inch proximal to the distal end, contained several detached sequestra lying in pus. In order to avoid shortening the stump, the cavity was saucerized by bevelling the distal three inches of the shaft. The muscles were then approximated over the end of the bone and the skin was closed without tension by interrupted silkworm-gut sutures with a wick of vaselined gauze for drainage. A massive dressing and pressure bandage were applied. Penicillin therapy was resumed and continued for five days. Systemic reaction was slight. Dressings were done with aseptic technic at intervals of from five to seven days, and drainage rapidly diminished. By April 1, 1945, complete healing had occurred and the stump was shrinking satisfactorily.

**COMMENT:** Early healing of this stump is attributed to complete removal of scar tissue and sequestra, collapse of healthy muscle against the bevelled end of the shaft and penicillin therapy before and after operation. Possibly, earlier healing might have occurred if penicillin could have been given for a longer time after the last operation.

#### SUMMARY

Of the serious persistent infections developing in wounds, probably at least half are caused by bacteria secondarily introduced. These can frequently be prevented and even established infection can be eliminated by meticulous operative technic supplemented by the administration of sulfonamides or penicillin before and after operation. This plan of management is described and two illustrations are cited.

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# TRAUMATIC SHOCK INCURABLE BY VOLUME REPLACEMENT THERAPY\*

A SUMMARY OF FURTHER STUDIES INCLUDING OBSERVATIONS ON THE  
HEMODYNAMICS, INTERMEDIARY METABOLISM AND THERAPEUTICS OF SHOCK

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IN A PREVIOUS COMMUNICATION<sup>1</sup> on traumatic shock we presented evidence that the capillaries outside areas of injury do not "leak" plasma, that the essential pathology is not a disturbed capillary permeability but rather a disturbed peripheral circulation, in which the amount of blood in active circulation through capillaries is deficient. The therapeutic problem is one of restoring normal velocity and volume flow through capillaries. When the disturbance has arisen from loss of blood or plasma, the problem is solved if replacement of loss is made early enough; if replacement is made too late, the problem is not solved by blood or plasma and *a state of irreversibility exists, i.e.,* the organism progressively and rapidly deteriorates and dies even after transfusion in adequate volume is given.† It is in this phase of the process that damage which is irreparable by known modes of therapy exists. Whether this damage consists in a loss of integrity inherent in the central or peripheral circulatory apparatus *per se*, or is secondary to the failure of an extravascular controlling factor is not known.

In this communication we will present data bearing on this problem under four headings: (1) A study of the altered hemodynamics due to viscosity changes; (2) an evaluation of existing therapeutic technics applied only to the irreversible stage of shock; (3) an inquiry into certain phases of intermediary metabolism in shock; and (4) observations on the effect of viviperfusion of the liver during hemorrhagic shock.

## I. THE EFFECT OF CHANGES IN BLOOD VISCOSITY UPON THE HEMODYNAMICS OF SHOCK

Although increased viscosity of the blood is properly regarded as an aggravating factor in the shock state, no precise evaluation of its importance

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\* The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Harvard University.

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† The shock resulting from bacterial toxins, *e.g.,* of the Welch bacillus or of *B. dysenteriae* is irreversible, in the sense defined above, from the beginning. Such shock displays all the attributes of advanced traumatic shock, is not amenable to transfusion at any stage and, if specific chemotherapy is unavailing, constitutes the same therapeutic problem presented by irreversible traumatic shock.

has been made. Tourniquet shock lends itself to such a study. This condition is representative of a variety of shock states in which, because of a selective loss of plasma, hematocrit and blood viscosity increase as blood volume falls. When many investigators of this condition reported therapeutic failure following replacement of the lost plasma, an explanation for death was sought in factors not directly concerned with altered hemodynamics. Since the muscles injured by the tourniquets show marked destruction and an infectious process at autopsy, bacterial toxins or toxins derived from damaged muscle were presumed to have an etiologic rôle in the development of the fatal shock process. For reasons given elsewhere<sup>2</sup> we do not regard these considerations relevant and have sought an explanation for the failure of volume therapy in the hemodynamic situation. Most previous investigators had induced shock by applying tourniquets for five hours, under barbiturate anesthesia. We repeated the experiment omitting barbiturates and utilizing only morphine. In these circumstances we found the shock, if it occurred at all, to be mild and easily cured by infusion of physiologic saline solution. It was, therefore, clear that in the experiments of previous investigators the shock was precipitated and intensified by the barbiturates and that failure in therapy in large part was due to the adverse effects of barbiturates. When we applied tourniquets for 8-11 hours in unanesthetized animals, shock occurred uniformly, but it was not fatal if replacement of plasma volume loss was made in time, *i.e.*, generally before the blood pressure had dropped below 60 mm. Hg. systolic. It was evident, however, that tourniquet shock became resistant to replacement of volume loss much earlier than is the case in hemorrhagic shock. If this decreased resistance were due to absorption of toxins (the circulation through the extremities was intact throughout the experimental period so that absorption of toxins into the general circulation could occur) 5 per cent albumin solution would not have been curative at any stage, as is the case in any type of toxic shock. The effectiveness of volume replacement therapy demonstrated that no explanation for the shock state other than the hemodynamic imbalance was necessary.

Further study of the hemodynamic imbalance showed that tourniquet shock differs from hemorrhagic shock in a number of particulars as follows:

TABLE I

	Hemorrhagic Shock	Tourniquet Shock
Fluid loss into localized areas	None	Large
Blood deficiency	Whole blood	Plasma
Hematocrit	Normal or low	65-85%
Relationship of hypotensive level of blood pressure and its duration to curability by transfusion	Transfusion curative even after BP remains at 30 mm. Hg. for hours	Transfusion not curative if BP remains below 80 for hours
Capillary circulation	Slow flow and few red cells in capillaries	Slow flow, but many red cells in capillaries
Sensorium	Not dull until blood pressure well below 40	Dull at pressure below 100
Tolerance to blood sampling	Relatively good until very low pressures are reached	Poor at pressures between 80 and 100



The striking differences relate to (1) hematocrit; (2) the critical level of blood pressure; and (3) the tolerance to bleeding. It is noteworthy that successful therapy in tourniquet shock is usually accompanied by a restoration of the high hematocrit to normal or less than normal values. It, therefore, is important to see to what extent the more precarious state of tourniquet shock as compared to hemorrhagic shock can be related to the high hematocrit alone. With this purpose in mind we studied the effect of high hematocrit upon blood pressure, cardiac output and peripheral resistance, adapting Poiseuille's equation

$$\text{Flow} = \frac{\text{Pressure}}{\text{Resistance}} \times \text{Constant}$$

to a system composed of nonrigid tubes and containing a nonhomogeneous fluid, as follows:

$$\text{Cardiac output} = \frac{\text{Blood pressure}}{\text{Total peripheral resistance}} \times K$$

The total peripheral resistance is the product of the blood viscosity ( $n$ ) and the resistance ( $R$ ) determined by number, length and caliber of peripheral vessels. Cardiac output, blood pressure and  $n$  are determined directly. The details of the method used for measuring  $n$  and for deriving  $R$  are published elsewhere.<sup>3</sup> Once these values and their interdependence are known, so that a constant ( $K$ ) for the normal animal can be evaluated, a standard is provided for the purpose of making comparable observations upon the dog in shock.

It was found that (1) an increase in blood viscosity has a deleterious effect upon cardiac output when the blood volume is deficient; (2) restoration of a high hematocrit to normal or below normal value improves cardiac output, but if simultaneous restoration of volume deficiency is not made, the increase in cardiac output is not enough to noticeably improve the shock state; and (3) at any level of reduced cardiac output the arterial blood pressure is higher when the blood viscosity is elevated—so that a deceptively favorable impression of the state of the circulation is given by the blood pressure reading. At blood pressure levels which are consistent with only a mild degree of hemorrhagic shock the cardiac output in tourniquet shock is already disproportionately low.

Hence, it is clear that the increased hematocrit of tourniquet shock is a liability over and above that of volume deficiency and can account for the observed differences between tourniquet shock and hemorrhagic shock. Volume deficiency is by far the greater danger and its restoration is a more urgent need than is that of normal viscosity. If an abnormally high viscosity exists in shock and is not treated effectively, the restoration and maintenance of normal blood volume becomes all the more urgent. The development of irreversibility to transfusion and the poor tolerance to bleeding in tourniquet shock at higher levels of blood pressure than in hemorrhagic shock is also explained by these findings.

## 11. THERAPY OF HEMORRHAGIC SHOCK IRREVERSIBLE TO TRANSFUSION

While the foregoing studies elucidate some of the hemodynamic mechanisms operating in certain circumstances, none of the observed changes in the hemodynamic equilibrium explains the failure of volume replacement to effect recovery after a period of time at pressures below 60.

Certain investigators<sup>4, 5</sup> insist that there is no time before death when restoration of adequate capillary flow cannot be achieved if only a sufficient amount of the right kind of fluid is given. Other agents also have been claimed to be effective even in late shock. It is necessary to be clear as to what we mean by late or so-called irreversible shock: It is that phase of shock which shows no sustained favorable response to the reinfusion of all the blood or plasma removed to induce the shock state. So long as no reliable method for confidently predicting the response to blood or blood substitute alone has been developed, claims made for the therapeutic value of any procedure or any substance other than blood or a blood substitute can be valid if effective alone and without restoring blood volume deficiency or if effective after an adequate transfusion has been shown to have failed. If the estimate of an agent's value is based upon its presumed effectiveness when given just before or along with blood or a blood substitute, unequivocal evidence must be provided to show that the latter alone would not have achieved the same result.

The following agents were studied with the foregoing considerations in mind: (1) Saline solution in large volume. (2) Whole blood. (3) Five per cent and 25 per cent albumin solution. (4) Alkali. (5) Pressor agents. (6) Succinic acid. (7) Coramine. (8) Various combinations of the foregoing agents.

Utilizing hemorrhagic shock and eliminating as far as possible operative manipulations, anesthetics and other forms of trauma, which facilitate the development of irreversibility or otherwise complicate the shock state, the agents listed were studied in every instance only after the shock state was found to be unresponsive to the replacement of all shed blood. The following results, discussed in detail elsewhere,<sup>6</sup> were obtained:

1. Massive infusions of physiologic saline solution may cause transitory improvement in circulation, but do not cure hemorrhagic shock irreversible to transfusion.

2. Massive infusions of isotonic (5 per cent) bovine albumin solution\* greatly increase the blood volume and may sustain the circulation for a time, but only rarely result in recovery. A marked bleeding tendency is produced by this therapy. Concentrated (25 per cent) bovine albumin solution in equivalent or greater protein content is of no benefit, even if supplemented by saline solution.

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\* The crystallized bovine serum albumin employed in this work was prepared at the Armour Laboratories, Chicago, Illinois, by the method of Cohn and Hughes, under a contract, recommended by the Committee on Medical Research, of the Office of Scientific Research and Development.

3. Large volume intravenous infusion therapy, using either physiologic saline solution alone or albumin in physiologic saline solution, is harmful by producing marked edema of tissues, pulmonary edema, serous effusions, venous distention and widespread hemorrhage from small vessels.

4. Pitressin with or without ergotamine is of no value. A combination of pitressin with 5 per cent albumin solution is not beneficial.

5. Paredrine\* (p - hydroxy - a - methylphenylethylamine hydrobromide) causes an elevation of the arterial and venous blood pressure. Venous sampling from various areas showed no evidence of preferential improvement of flow into such vital areas as the brain and liver. No improvement in cardiac output, oxygen content of venous blood or capillary flow was noted. The duration of the pressor effect is limited by the rapid development of unresponsiveness to the drug and survival time is not prolonged.

6. Hypertensin, a product of the constant interaction of renin, of renal origin, and hypertensinogen, of hepatic origin; when continuously administered, causes an elevation of blood pressure, an increase in the volume and velocity flow through capillaries, a rise in  $O_2$  saturation of venous blood toward normal and a rise in cardiac output. Unfortunately, the dog in shock becomes increasingly tachyphylactic to this as to other drugs, so that increasing doses must be given to obtain a continuing effect. The amount required to sustain one dog for an hour or two is enormous in terms of the labor and material involved in the present methods of preparation of hypertensin. This substance is of academic rather than of practical interest at present—for even when enough material was available for a few experiments, responsiveness to it was not sustained long enough to reverse the shock process.

7. Coramine (pyridine-beta-carboxylic acid diethylamide) increases skeletal muscle tone, but does not favorably influence the course of events.

8. The correction of acidosis by the administration of sodium bicarbonate with, or subsequent to, the initial transfusion does not alter the deteriorating trend of advanced hemorrhagic shock.

9. Sodium succinate is of no benefit in the therapy of advanced hemorrhagic shock.

10. Tuamine, given when the initial transfusion is failing, causes a transitory rise in blood pressure. Survival time is not prolonged.

11. Potassium phosphate† intracisternally does not alter the deteriorating trend of hemorrhagic shock and at the same time produces undesirable cerebral excitatory phenomena.

The completely negative value of such a large variety of agents is at variance with the claims made by various investigators. Allen,<sup>4</sup> and Warren, *et al.*,<sup>5</sup> presented data to the effect that the deteriorating trend in shock in any

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\* Most vasopressor drugs are considered deleterious because they add to the already increased vasoconstriction with resulting further depletion of capillary flow. Since most of these drugs exert metabolic effects as well, which paredrine does not, this drug was studied extensively.<sup>7</sup>

† This drug, suggested by Russian investigators, was provided through the courtesy of Dr. Baird Hastings, Department of Biochemistry, Harvard Medical School, Boston, Mass.

stage can be halted or even reversed by intravenous physiologic saline solution given in sufficient volume for a sufficient length of time, with care to avoid fatal pulmonary edema. Survival was explained as due to the creation of a sufficiently high interstitial pressure so as to reverse the flow of fluids from out to into the circulatory bed. The therapeutic value of saline solution is not confirmed by our data on hemorrhagic shock, even though the volume of saline solution was adequate to achieve the tissue pressures demanded by such a postulate.

Evidence of recovery from shock includes a sustained rise in cardiac output, in acceleration of capillary flow, in oxygen content of the mixed venous blood and in blood pressure. Such changes, readily achieved during the early shock phase by transfusion, do not persist following the infusion of large volumes of fluid of any kind if given after the initial transfusion has failed. The futility of infusion of relatively huge volumes of fluids which do not escape or escape only slowly from the circulation (*e.g.*, albumin solution) demonstrates that even when there is no significant continuing loss of fluid, as in irreversible hemorrhagic shock, conditions exist that are no longer amenable to the restoration and successful maintenance of a normal or more than normal blood volume.

The infusion of large amounts of albumin or whole blood, with Ringer's solution containing alkali, is not only not effective in hemorrhagic shock, but leads to pulmonary edema and to considerable bleeding in open wounds and in the intestine. Moyer, *et al.*,<sup>8</sup> recommended the clinical use of physiologic saline and soda bicarbonate solution plus defibrinated blood in the treatment of burns. The recommendation may be classified with those of Fox,<sup>9</sup> and of Rosenthal,<sup>10</sup> who report a favorable response of burned patients and of rats respectively to electrolyte solutions. Since the data offered by these authors do not demonstrate conclusively that the acute hemodynamic imbalance of shock existed, any inference made, or implied, that these therapeutic measures are of value for the treatment of advanced traumatic shock from any cause is unjustified.

Wiggers and Werle<sup>11</sup> believe that declining myocardial efficiency is to some extent responsible for the progressive decline in the late shock phase. Recently, Page<sup>12</sup> identified, by cardiometric observations on the exposed heart, a measure of cardiac weakness which was not reversible by any known methods of therapy except certain aliphatic amines (one-amine, tuamine, *etc.*) with specific myocardial stimulating qualities. In six experiments with our technic of determining irreversibility, tuamine produced no rise in cardiac output or other beneficial response except a transient rise in systolic pressure. The effect of tuamine was analogous to that of paredrine. Our experiments differed from those of Page in that he gave the drug with, or immediately after, transfusion, whereas, we withheld the drug until the response to transfusion alone had been found ineffective.

Henderson<sup>13</sup> attributes the fault in the circulation in shock to a loss of skeletal muscle tone, with consequent failure of venous pressure and return flow. In our experiments with coramine, which increases skeletal muscle tone

to the point of extreme rigidity, blood flow was not improved. A more desirable physiologic technic to test the Henderson hypothesis would provide for alternating contraction and relaxation of muscle.

Chambers, *et al.*,<sup>14</sup> believe that the primary deficiency lies in the collapse of the contractile power (vasomotion) of arterioles and venules, which in late shock lose their reactivity to adrenalin. They report a favorable response<sup>15</sup> from the use of pitressin, with and without ergotamine, given with, and subsequent to, transfusion. In our experiments these agents were given without transfusion or after the transfusion was shown to be ineffective. No benefit was observed.

Uncompensated acidosis has long been known to persist in the untreated late shock phase and the alkali therapy introduced by Cannon<sup>16</sup> during World War I has recently been recommended by Levine, *et al.*,<sup>17</sup> who attribute to sodium bicarbonate the capacity to reverse and to cure a degree of shock not amenable to transfusion alone. They accept as a test for such a degree of shock not the fact of a futile transfusion already given, but a CO<sub>2</sub> combining capacity of 15 volumes per cent or less. In our experiments, when alkali was given to correct acidosis and to maintain a normal or higher than normal CO<sub>2</sub> combining capacity thereafter, the deteriorating trend following transfusion was not noticeably alleviated.

The tolerance of the organism to hemorrhage, when the latter is induced by the withdrawal of blood by simple needle puncture of a large artery in the intact unanesthetized and unimmobilized dog, contrasts sharply with that of the dog anesthetized, immobilized, cannulated and otherwise traumatized. This points out the need of excluding as far as possible all extraneous factors, if the shock due to volume loss alone is to be properly evaluated.\* The more such factors are eliminated, the more difficult it becomes to produce irreversibility to transfusion, which then is achieved by prolonging the time and increasing the degree of hypotension. Our experiments approached the ideal of simplification only very approximately, for we used morphine and open wounds and a considerable degree of immobilization in order to obtain essential data not otherwise possible. The factor of sepsis is of dubious import, because of the absence of pathologic evidence of its presence in these experiments, and because the experimental period seems too short for the production of significant amounts of bacterial toxin. Even if bacteremia is common in these circumstances, it remains to be shown that the kind of organisms, their number and

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\* Experiments reported by Schachter (*Am. J. Physiol.*, 143, 552, 1945) are a case in point. He reports that cholinesterase cures traumatic shock induced by intestinal manipulation in anesthetized hyperthyroid dogs. From his hematocrit data there is reason to believe that the plasma volume loss would not have been sufficient to induce fatal shock in unanesthetized nonhyperthyroid dogs. Presumably shock was precipitated by the superimposed aggravating factors of barbiturate anesthesia and hyperthyroidism. Plasma volume therapy failed in such dogs for the same reason that it fails in five-hour tourniquet shock induced under barbiturate anesthesia. The favorable action of cholinesterase in these experiments may have been exerted upon the accessory aggravating factors and does not justify a conclusion that cholinesterase is of value in the treatment of shock *per se*.

virulence, were of sufficient consequence during the period of experimentation to have influenced the results. Reduced to the simplest conditions it is possible to achieve experimentally, we believe that the course of events in hemorrhagic shock leading to the development of a state of irreversibility to transfusion is a function of the severity and duration of inadequate capillary flow, with a resulting cumulative adverse effect on the integrity of cellular function in general or on a basic biochemical function in a controlling vital organ such as the liver.

### III. INTERMEDIARY METABOLISM IN SHOCK

Ample evidence is available of serious disturbances in kidney, liver and intestinal function<sup>18</sup> and of extensive biochemical abnormalities, especially in intermediary carbohydrate metabolism.<sup>19</sup>

Phosphorylation of enzymes essential in carbohydrate breakdown and resynthesis is seriously affected in shock.<sup>20, 21</sup> The lack of substrates normally available for energy release has led to efforts to replace them by others present in tissues but not necessarily serving this purpose, *e.g.*, succinic acid.\*

Van Slyke<sup>24</sup> has succeeded in defining the limits of anoxia which the kidney can endure before irreparable damage to function results. But the effects of loss of kidney function, while capable of causing death within a few days, are not, as far as is known, operative within the shock period.† Collapse of liver function might well result in irretrievable effects and explain death within the shock period. A measure of such collapse might be reflected in aberrations from the normal sequence of reactions in intermediary metabolism.

Our primary purpose in undertaking studies of the intermediary metabolism in shock was to discover, if possible, some point in the process of biochemic disintegration, *i.e.*, failure of completion of a normal biochemic reaction, which would identify the onset of irreversibility. Thus, a tolerance test to intravenously injected carbohydrate or protein intermediates might disclose a time of crucial metabolic collapse paralleling the onset of irreversi-

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\* When Shorr, *et al.*,<sup>22</sup> showed that this substance *in vitro* increases oxygen consumption of tissue slices at low oxygen tensions, Mylon and Winternitz,<sup>23</sup> and Levine, *et al.*,<sup>17</sup> reported substantial improvement in the shock state as a result of its administration. We were unable to substantiate these claims in tourniquet shock<sup>2</sup> or in hemorrhagic shock.<sup>6</sup> Recently, Shorr,<sup>22</sup> and Meyer and Potter,<sup>20</sup> have found that the increased oxygen consumption at low oxygen tensions produced by succinic acid is at the expense of the tissue needs for normal function and to this extent succinic acid can be regarded as deleterious rather than helpful.

† Anuria resulting from organic disturbance of the kidneys is a common experience in military surgery following extensive wounds. Frequent reports from the European Theater of War refer to such patients as responding well to the initial therapy for shock, only to die later in uremia. The kidneys show casts in the tubules or cloudy swelling, or both, and no known treatment has been of any value. For such cases and for patients in shock who show deficient renal function because of prolonged ineffectively treated periods of hypotension, it is desirable, if possible, to develop a temporary substitute for kidney function, so that uremic death may not result during the time necessary for recovery of kidney function. Experiments to be reported<sup>25</sup> show that continuous peritoneal irrigation for days in nephrectomized dogs, before and after the development of uremia, is capable of preventing or removing the accumulation of nitrogenous substances in the blood.

bility. For this purpose we performed tolerance tests for glucose, lactic acid, pyruvic acid and a variety of amino-acids in various phases of shock. The accumulation of the latter three normal metabolites in the blood in shock is progressive.

Engel, *et al.*,<sup>19</sup> state that the increasing amino-acid level is an index of failure of deamination by the liver. Our tolerance curve studies showed (1) that all these metabolites, including the amino-acids, are catabolized as readily in the irreversible as in the reversible phase of shock, indeed, almost as well as in the normal animal; and (2) the increased concentration of these substances in the blood represents an adjustment of metabolic reactions at a new level. The detailed data in support of these conclusions will appear in a subsequent paper.<sup>26</sup>

#### IV. VIVIPERFUSION OF THE LIVER

Failing in our effort to correlate the development of irreversibility to a serious disruption in these processes, we proceeded to an investigation of the liver as a likely example of a vital organ whose controlling influence, if lost, may constitute the primary cause of death. There is evidence of severe liver injury in shock: (1) This organ receives much of its blood supply from the portal vein, which in shock has a much reduced volume flow of blood with a very low oxygen content. (2) Excretion of bromsulfalein is much reduced in shock. (3) The duration of survival following total hepatectomy is comparable to that following the onset of hemorrhagic shock and the blood chemistry of the two conditions is not dissimilar.<sup>27</sup> (4) The liver is soft, friable and discolored at death from hemorrhagic shock.

Although the rôle of the liver is still being actively studied, certain preliminary results of interest may be referred to herewith. Our approach to this problem consisted in an experimental set-up aimed at preserving the integrity of the liver,<sup>28</sup> while the remainder of the organism is exposed to the general effects of the shock state. This was carried out as follows: The splenic vein of a healthy dog is prepared for cannulation. Hemorrhagic shock is induced. One carotid artery of a donor dog is connected to the splenic vein of the dog in shock. Both femoral arteries of the dog in shock are connected to one femoral vein of the donor. In the delivery and return circuits calibrated manometers, constructed on the Bernouille principle, are introduced. Both dogs and the entire connecting system are heparinized. The dog in shock has been bled and when the blood pressure has been stabilized at a level of some 30 mm. Hg. all circuits are opened and the shocked dog receives through the splenic vein some 350-450 cc. of arterial blood per minute\* from the donor dog. Volume flow to and return from the dog in shock is controllable and is readily equalized by adjustable clamps on the connecting tubes, so that over a period of hours no measurable difference between volume delivery and return is observed.

Experience has demonstrated that nearly all dogs in hemorrhagic shock,

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\* This volume flow of blood approximates the portal flow through the liver in a normal dog.<sup>27</sup>

maintained at a pressure of 30 mm. Hg. for from 1.5–3 hours, will be unresponsive to transfusion. Such dogs connected to an elevated bottle containing the shed blood will begin to take blood back from this reservoir as they approach the state of rapid collapse. When they have taken from one-third to one-half of the shed blood volume, well over 80 per cent will show no sustained response following the rapid reinfusion of the remainder. This "taking-up" process therefore may be used as probable evidence of the onset of irreversibility. In the viviperfusion experiments the dog in shock, as soon as its blood pressure begins to give way, "takes-up" from the donor dog, which, like the elevated bottle, acts as a supply reservoir. This is registered in terms of a decline in donor blood pressure and is measured approximately by noting the amount of blood taken in advance from a third dog which is required to return the donor blood pressure to its original level. When one-third to one-half of the shocked dog's shed blood volume has been taken up, the dog is regarded as probably irreversible. At this point the cross-circuits are closed and disconnected and the dog in shock is then given back all the shed blood. Nothing further is done. Posttransfusion observations are made and survival time observed. The same technic was used on a control group of dogs in which the jugular instead of the splenic vein was used as the route for viviperfusion.

All but one of 15 dogs in the control group died as soon as and with the same pathologic manifestations as dogs in irreversible hemorrhagic shock which are not cross-circulated. All but one of 12 dogs whose livers were perfused survived. Immediately after transfusion they were active, able to stand up and drink water. They showed no subsequent evidence of renal damage.

The uniformity of the results in each of the two groups establishes the importance of the liver in the shock process and the significance of the damage which it suffers after several hours of reduced volume and velocity of flow of anoxic blood. By preventing liver damage, irreversibility to transfusion is prevented. It is, therefore, not necessary to postulate widespread irreparable damage to cellular function in order to account for the onset of irreversibility to transfusion. Whether damage to the liver, if allowed to occur, is reversible will be determined by beginning the viviperfusion only after transfusion has been shown to have failed.

The prevention of the development of irreversibility by viviperfusion of the liver is not due to the removal of toxins or to the provision of protective substances by the donor dog during the shock phase, because the same processes operate in the dog viviperfused *via* the jugular vein.

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# TRANSLOCATION OF FLUID PRODUCED BY THE INTRAVENOUS ADMINISTRATION OF ISOTONIC SALT SOLUTIONS IN MAN POSTOPERATIVELY\*

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DURING THE PAST DECADE several papers from this clinic<sup>1, 2, 3</sup> have pointed out certain possible, undesirable complications attendant upon the unwise use of intravenous isotonic sodium chloride solution. It has been emphasized<sup>3</sup> that these dangers are increased many fold during the immediate postoperative period of the sick surgical patient. This concept is neither new nor original, since many authors<sup>4</sup> have directed attention to the potential toxicity of so-called "physiologic saline," especially when large amounts are administered.

Studies to determine the manner in which the human body handles large intravenous infusions of "salt" solutions were undertaken in patients undergoing combined abdominoperineal resections for carcinoma of the rectum. An explanation of the "salt intolerance" was sought in the excretions and retentions of sodium, chloride and water in the 30-hour period beginning with the operation. Solutions of various composition and tonicity were infused at regular intervals during this period.

The study was divided into five six-hour periods. The initial infusion was started at the beginning of the operation and the rate of administration was determined by the exigencies of the operation. The second infusion was started six hours after the first infusion. This, and subsequent infusions, were administered at approximate rates of 250 Ml. per hour for the smaller amounts and 400 Ml. per hour for the larger volumes.

Weighed dressings covered with oiled silk were applied to the anterior and posterior wounds. These dressings were changed and reweighed every 12 hours (three determinations of losses from wound drainage). In the balance studies, such losses were considered as an ultrafiltrate of plasma, since loss of blood was visibly small.

Urine was collected during the five periods and preserved with thymol and refrigeration. Two samples of blood, one with heparin and one under oil, were withdrawn before operation, at the end of operation, and at the end of the final infusion period. The urines were analyzed for specific gravity,  $pH$  by glass electrode, potassium by the method of Fiske and Litarczek,<sup>5</sup> sodium by the method of Butler and Tuthill,<sup>6</sup> ammonia by the method of Folin and Bell,<sup>7</sup> chloride by the method of Logan,<sup>8</sup> sulfate by the method of Fiske,<sup>10</sup> phosphate by the method of Fiske and Subbarow,<sup>10</sup> total nitrogen by

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the micro-kjeldahl method of Pregl,<sup>11</sup> urea,<sup>12</sup> and carbon dioxide<sup>13</sup> by the methods of Van Slyke, and creatinin by the method of Popper.<sup>14</sup> Heparinized whole blood was analyzed for hematocrit by use of capillary tubes, for specific gravity by the method of Barbour and Hamilton,<sup>15</sup> and for hemoglobin by the photo-electric method of Evelyn.<sup>16</sup> Serum proteins were calculated from the specific gravity of the sera according to the formula of Weech.<sup>17</sup> Serum was analyzed for sodium, carbon dioxide content and chloride.

Blood loss during operation was estimated, and in almost all cases found to correspond to the average figures previously reported by this clinic.<sup>18</sup>

*Procedure and Method of Calculation:* The patients who served as subjects were selected only in that they were determined to be free of gross cardiovascular and kidney disease. They were prepared for operation by sulfasuccidine and Miles' regimen. If the hemoglobin was below 80 per cent, they were transfused before operation. The preanesthetic medication consisted of morphine in combination with barbiturates. Operations were performed under spinal anesthesia with either nupercaine or continuous procaine. Pre-operatively, an indwelling catheter was introduced, which remained in place throughout the study.

All intake was by the intravenous route. The first five cases received 3,750 Ml. of 0.9 per cent NaCl in five equal infusions during the first 30 hours after operation. Three patients received 3,750 Ml. of 0.75 per cent NaCl plus 0.22 per cent NaHCO<sub>3</sub>, an adjusted salt solution containing a physiologic amount of NaHCO<sub>3</sub> (26 mEq. per liter). One patient received 5,625 Ml. of 0.6 per cent NaCl, a solution physiologic with respect to chloride. Three patients received 7,500 Ml. of 0.45 per cent NaCl, and one patient, 7,500 Ml. of 0.375 per cent NaCl plus 0.11 per cent NaHCO<sub>3</sub>.

In-put of sodium was kept constant at 578 mEq. except in the case of one patient, a small individual who received 80 per cent of the established infusion. Since the nutritional status of these patients with neoplastic disease could only be judged by body weight, and the preformed water contained in the water evaporated from lungs and skin and given off in the urine could only be guessed at, this preformed water has been ignored in the calculations of load of water. However, in Benedict's fasting subject, Levanzin, preformed water amounted to 585 Gm. during the first 24 hours of the fast.<sup>19</sup>

Water gained as a result of the breakdown of body protein was calculated from the urinary nitrogen by use of the factor 6.25 and the equation: water = 0.27 liters per 100 Gm. protein.<sup>20</sup> Insensible loss was estimated for all patients as 0.07 per cent of body weight per hour, as suggested by Adolph.<sup>21</sup> This value is based upon studies of normal individuals and in all probability is too conservative an estimate of losses by patients immediately post-operatively.

Water balance, thus, becomes in-put plus oxidative gain less the combined losses by way of the urine, wounds, lungs and skin. Sodium and chloride balances are calculated from in-put less urinary and wound losses.

*Results:* Table I summarizes the changes in the blood and serum of eight

patients receiving the five types of infusion. There is evidence that all patients handled the infusions fairly efficiently with the probable exception of Patient St. The best examples of this efficiency are the small changes produced in the concentrations of sodium and chloride in the sera of the patients receiving large infusions of hypotonic solutions. Serum proteins are lowered in every case, regardless of the volume of solution infused.

Table II presents the urinary concentrations of potassium, sodium, chloride, and the ratios of sodium to chloride of all patients during the first 24 hours

TABLE I  
CHANGES IN THE BLOOD AND SERUM OF EIGHT PATIENTS RECEIVING THE VARIOUS INFUSIONS

Patient—Infusion	Blood			Serum			
	Hemato- crit Vol. %	Hemo- globin Gm. %	Specific Gravity	Protein Gm. %	Carbon Dioxide* Vol. %	Chloride mEq./l.	Sodium mEq./l.
Br ♂ 0.9% NaCl	Preop.	43.0	14.9	1.0556	6.12	60.1	101.3
	Postop.	40.0	12.4	1.0476	5.27	57.4	103.2
	30 hrs.	37.3	11.6	1.0438	3.35	48.9	108.7
St ♀ 0.75% NaCl + 0.22% NaHCO <sub>3</sub>	Preop.	40.5	12.6	1.0501	6.19	58.4	104.2
	Postop.	17.5	6.0	1.0283	3.20	55.2	115.4
	33 hrs.	16.2	6.8	1.0363	5.21	58.9	105.0
Vo ♂ 0.75% NaCl + 0.22% NaHCO <sub>3</sub>	Transfus.	25.3	8.2	1.0397	5.24	63.3	106.7
	Preop.	43.9	14.2	1.0524	5.44	68.9	102.7
	Postop.	51.5	15.4	1.0551	5.62	71.8	103.0
Mo ♂ 0.6% NaCl	30 hrs.	40.0	12.4	1.0494	5.03	64.0	104.3
	Preop.	43.4	14.6	1.0546	6.50	64.2	100.8
	Postop.	44.4	13.7	1.0521	5.85	58.8	102.7
Hu ♂ 0.38% NaCl + 0.11% NaHCO <sub>3</sub>	30 hrs.	36.9	12.1	1.0473	4.96	55.1	102.5
	Preop.	50.7	15.7	1.0559	6.19	62.6	97.8
	Postop.	44.8	13.5	1.0486	4.90	58.7	99.9
Le ♂ 0.45% NaCl	30 hrs.	42.0	12.7	1.0486	4.76	56.5	99.9
	Preop.	48.9	15.4	1.0585	6.25	63.8	102.3
	Postop.	47.0	14.2	1.0571	6.12	53.2	102.0
Sm ♀† 0.45% NaCl	30 hrs.	33.3	10.5	1.0435	4.86	53.5	95.8
	Preop.	47.3	15.2	1.0582	7.01	56.5	100.7
	Postop.	42.8	13.0	1.0512	5.58	59.3	101.7
Re ♂ 0.45% NaCl	30 hrs.	45.9	12.5	1.0501	5.11	53.8	94.8
	Preop.	50.5	16.4	1.0607	6.63	57.7	103.3
	Postop.	49.2	15.2	1.0507	6.50	66.7	101.0
	30 hrs.	28.3	9.5	1.0422	4.63	53.2	99.4

\* Content.

† Patient Sm received 80% of the infusion.

postoperatively. It is noteworthy that the two patients receiving the adjusted salt solution and the hypotonic, adjusted salt solution were the only subjects who excreted sodium and chloride in ratios approximating that of an ultrafiltrate of plasma.

Table III summarizes the loads of sodium, chloride and water at the end of 30 hours' infusion for eight patients receiving the various infusions.

The complete data, except for blood changes, are presented in Figures 1 through 6. Loads of water, sodium and chloride, and urinary losses of sodium, chloride, potassium, phosphate, sulfate and nitrogen are charted as cumulative balances and losses throughout the 30-hour period. The nitrogen scale has been adjusted to correspond to the nitrogen to potassium ratio existing in tissue. As a result, Figures 1 to 6 stress the presence of "excess

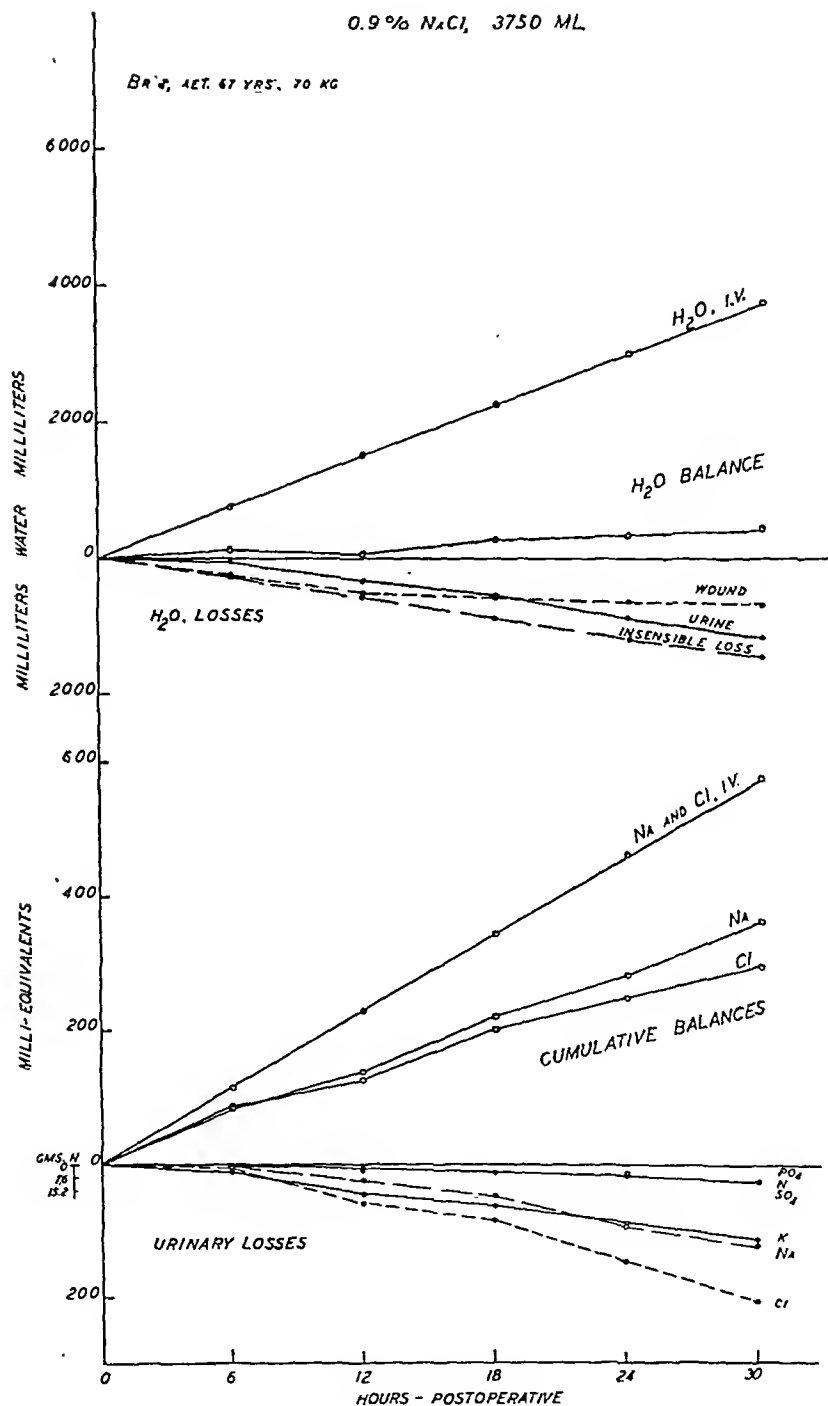


FIG. 1.—Cumulative balances of water, sodium and chloride, and losses of water and urinary constituents of patient Br., m., No. 565,142, who received 3750 ml of 0.9% NaCl in five equal infusions during 30 hours following combined abdominoperineal resection for carcinoma of the rectum. The patient was not prepared for operation by Mile's regimen because of a cecostomy performed 19 days before. Operation was performed under continuous procaine spinal. Postoperative course was uneventful, except for a mild, transitory hypotension lasting for six hours after operation.

# SALT SOLUTIONS POSTOPERATIVELY

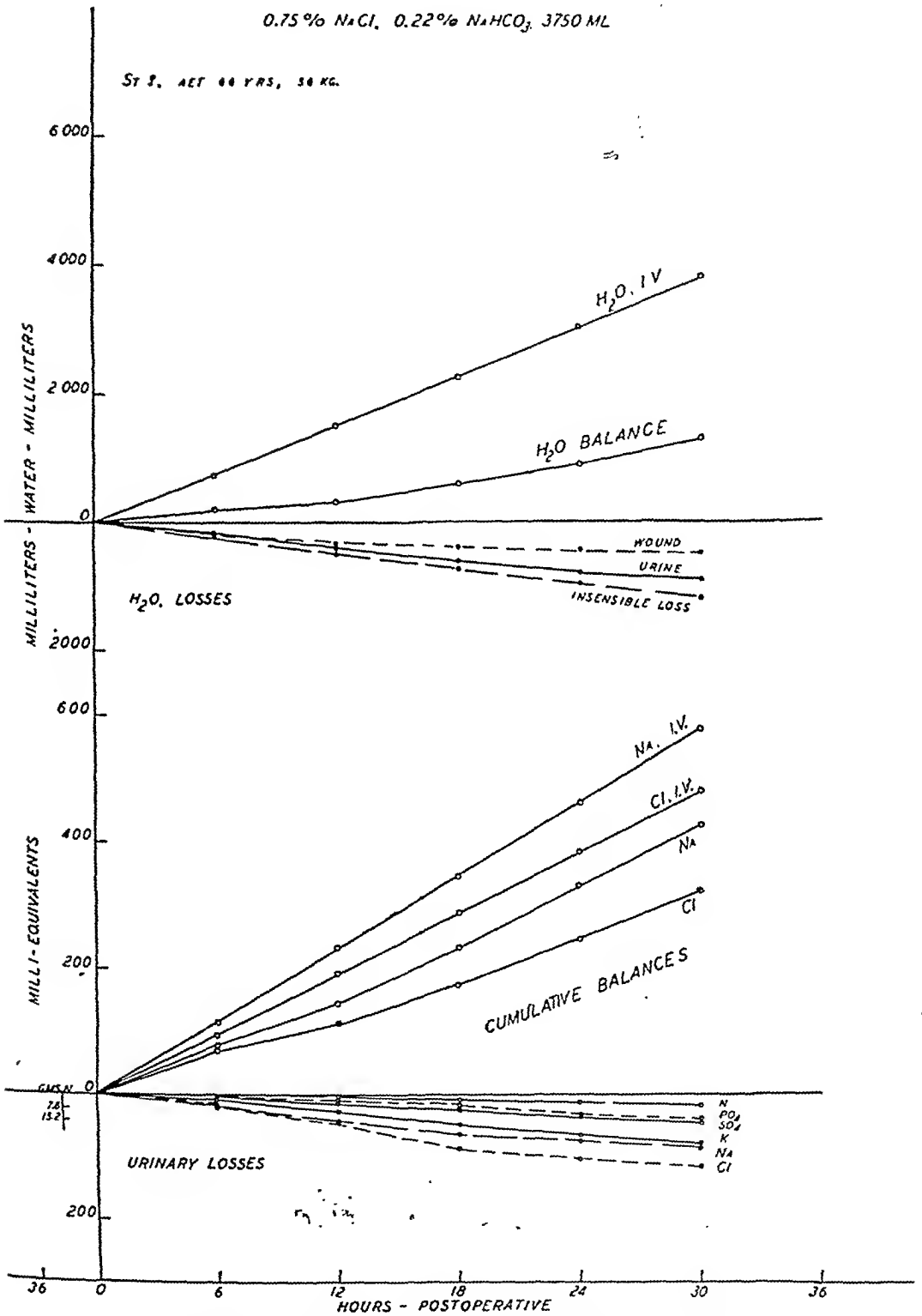


FIG. 2.—Cumulative balances of water, sodium and chloride, and losses of water and urinary constituents of patient St., f., No. 563,726, who received 3750 ML. of 0.75% NaCl plus 0.22% NaHCO<sub>3</sub> during 30 hours following combined abdominoperineal resection. Operation was performed under continuous procaine spinal anesthesia. There was marked hypotension during the operation, and the postoperative course was characterized by tachycardia and hypotension. The patient received a transfusion of 500 ML. of blood at the end of the infusion period.

potassium" excreted by all the patients studied. Judging from the losses of Levanzin, about 40 mEq. of the potassium are due to starvation. The remainder may be attributed in part to tissue trauma, in part to the infusion of 34 Gm. of salt. As shown by Gamble,<sup>22</sup> the addition of extracellular electrolytes causes a large transfer of intracellular water to the extracellular compartment. The removal of intracellular electrolyte follows in order to

TABLE II

URINARY EXCRETION OF POTASSIUM, SODIUM AND CHLORIDE IN 24 HOURS POSTOPERATIVELY

Patient—Infusion	Urine Volume Ml.	Potassium mEq./l.	Sodium mEq./l.	Chloride mEq./l.	Ratio Na:Cl	Comment
Br ♂ 0.9% NaCl (3000 Ml.)	886	97.9	105.2	165.0	0.64	Miles' regimen not used. Wound loss: 630 Gm.
Ke ♂ 0.9% NaCl (3000 Ml.)	579	92.5	94.6	147.3	0.64	Infusion in one dose postoperatively
Br ♀ 0.9% NaCl (3000 Ml.)	891	117.4	93.8	135.2	0.69	First day
Mo ♀ 0.9% NaCl (3000 Ml.)	831	80.1	25.1	53.9	0.47	Infection, 2nd day
Mo ♀ 0.9% NaCl (3000 Ml.)	944	54.8	168.0	216.1	0.78	
Li ♀ 0.9% NaCl (3000 Ml.)	990	46.3	187.6	232.6	0.81	500 Ml. blood post- operatively
Fe ♂ 0.75% NaCl + 0.22% NaHCO <sub>3</sub> (3000 Ml.)	1230	116.7	168.0	154.3	1.09	First day
St ♀ 0.75% NaCl + 0.22% NaHCO <sub>3</sub> (3000 Ml.)	1380	81.0	154.8	150.5	1.03	Second day
St ♀ 0.75% NaCl + 0.22% NaHCO <sub>3</sub> (3000 Ml.)	735	87.0	98.0	126.0	0.78	Wound loss: 395 Gm.
Vo ♂ 0.75% NaCl + 0.22% NaHCO <sub>3</sub> (3000 Ml.)	1070	129.2	120.7	81.3	1.48	Wound loss: 610 Gm.
Mo ♂ 0.6% NaCl (4500 Ml.)	1186	100.6	91.0	124.8	0.73	Wound loss: 665 Gm.
Hu ♂ 0.38% NaCl + 0.11% NaHCO <sub>3</sub> (6000 Ml.)	895	101.3	138.3	112.1	1.23	Wound loss: 400 Gm.
Le ♂ 0.45% NaCl (6000 Ml.)	1170	129.5	121.2	141.5	0.86	Wound loss: 1375 Gm.
Re ♂ 0.45% NaCl (6000 Ml.)	491	106.5	15.2	52.5	0.29	Wound loss: 1826 Gm.
Sm ♀ 0.45% NaCl (4800 Ml.)	1321	72.1	95.4	102.1	0.93	Wound loss: 991 Gm.

preserve normal ionic concentration during the period of stress created by the load of salt. However, this explanation is scarcely adequate to account for the excess potassium in those cases receiving the large infusions which provided sufficient water. From Table II, it is evident that loss of potassium can be correlated with the volume of urine excreted.

Figure 1, Patient Br, ♂, 3,750 Ml. of 0.9 per cent NaCl, describes a very small balance of water at the end of 30 hours, a large load of sodium and chloride, a moderate loss of fluid from the posterior wound. The urinary excretion of chloride exceeded that of sodium.

Figure 2, Patient St, ♀, 3,750 Ml. of 0.75 per cent NaCl and 0.22 per cent NaHCO<sub>3</sub>, indicates a greater load of water and a greater load of sodium and chloride, but the actual retention concentrations are less than those of

Figure 1. More chloride than sodium is lost in the urine, but the difference is small.

Figure 3, Patient Mo, ♂, 5,625 Ml. of 0.6 per cent NaCl, describes a positive load of water, a marked diuresis after 24 hours (a fact established by Bayliss and Fee<sup>23</sup> for 0.6 per cent NaCl in dogs), a minimal loss from wounds, large urinary "excess potassium" and a greater excretion of urinary

TABLE III  
THIRTY-HOUR LOADS OF SODIUM, CHLORIDE AND WATER

		In-put	Oxidative	Urine	Excretion	Insensible	Load
		mEq. or Ml.	Water Ml.	mEq. or Ml.	Wound mEq. or Ml.	Loss Ml.	mEq. or Ml.
Br 0.9% NaCl	Na	577.5		119.6	93.0		364.9
	Cl	577.5		205.0	72.6		299.9
	H <sub>2</sub> O	3750	161	1174	694	1470	573
St 0.75% NaCl + 0.22% NaHCO <sub>3</sub>	Na	579.5		85.8	65.5		428.2
	Cl	481.0		118.1	49.5		323.4
	H <sub>2</sub> O	3750	94	885	450	1180	1329
Vo 0.75% NaCl + 0.22% NaHCO <sub>3</sub>	Na	579.5		158.0	110.6		310.9
	Cl	481.0		112.6	86.9		281.5
	H <sub>2</sub> O	3750	218	1320	790	1640	218
Mo 0.6% NaCl	Na	577.5		189.0	120.2		268.3
	Cl	577.5		239.6	92.3		245.6
	H <sub>2</sub> O	5625	200	2416	855	1470	1084
Hu 0.38% NaCl + 0.11% NaHCO <sub>3</sub>	Na	577.5		263.5	119.7		194.7
	Cl	577.5		212.8	90.5		177.7
	H <sub>2</sub> O	7500	204	1495	905	1470	3834
Le 0.45% NaCl	Na	577.5		227.3	201.6		148.6
	Cl	577.5		264.5	152.9		150.1
	H <sub>2</sub> O	7500	194	2130	1390	1510	2664
Sm 0.45% NaCl	Na	462.0		200.3	187.4		73.8
	Cl	462.0		225.6	142.2		85.5
	H <sub>2</sub> O	6000	216	2044	1293	1010	1869
Re 0.45% NaCl	Na	577.5		10.9	375.8		190.8
	Cl	577.5		25.9	285.1		266.4
	H <sub>2</sub> O	7500	79	506	2592	1470	3011

chloride. At the end of 48 hours, the patient had received 200 Ml. of orange juice and 250 Ml. of water, the sodium load was reduced to 164 mEq., the chloride load to 116 mEq. and the water load to —38 Ml.

Figures 4 and 5 are presented to contrast the paths of excretion of large volumes of fluid. Both patients received 7,500 Ml. of 0.45 per cent NaCl. Patient Le, ♂, Figure 4, showed a large load of water, a marked increase in the loss from wounds, a diuresis after 24 hours, a greater urinary excretion of chloride than of sodium, and the smallest load of NaCl of the patients charted. Patient Re, ♂, Figure 5, was hypotensive after the operation. The volume of urine excreted was very small, the quantity of sodium and chloride negligible. Such massive losses of fluid from the posterior wound occurred that the final loads of sodium, chloride and water were not unlike those of Figure 4.

Figure 6, Patient Hu, ♂, 7,500 Ml. of 0.375 per cent NaCl and 0.11 per cent NaHCO<sub>3</sub>, shows the largest water retention of the group and a pronounced urinary loss of both sodium and chloride, with sodium predominating.



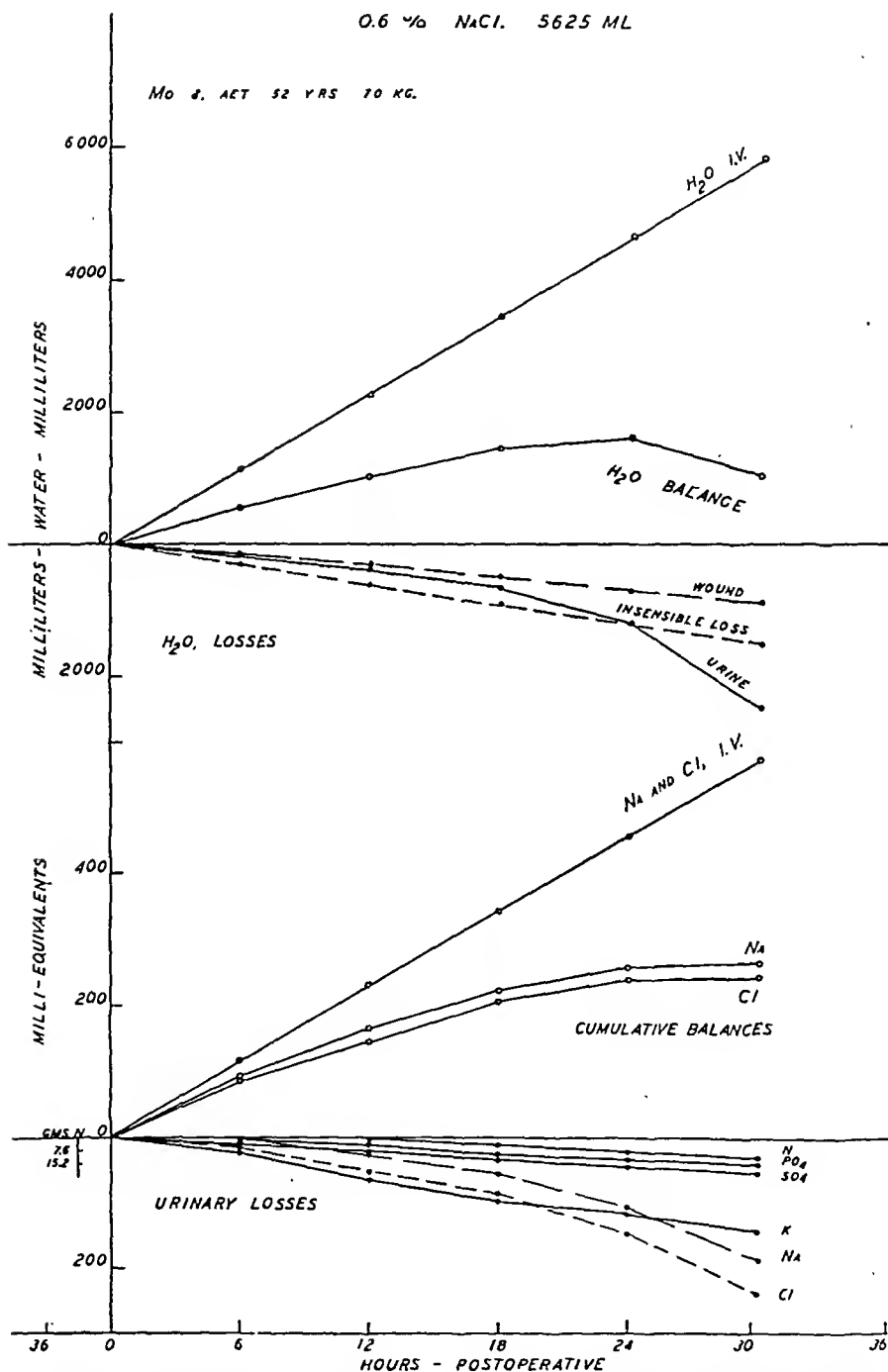
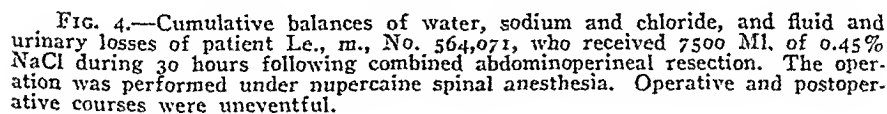


FIG. 3.—Cumulative balances of water, sodium and chloride, and losses of water and urinary constituents of patient Mo., m., No. 568,132, who received 5625 ML. of 0.6% NaCl during 30 hours following combined abdominoperineal resection. Operation was performed under continuous procaine spinal anesthesia. Hypotension did not develop, and the postoperative condition of the patient was excellent.



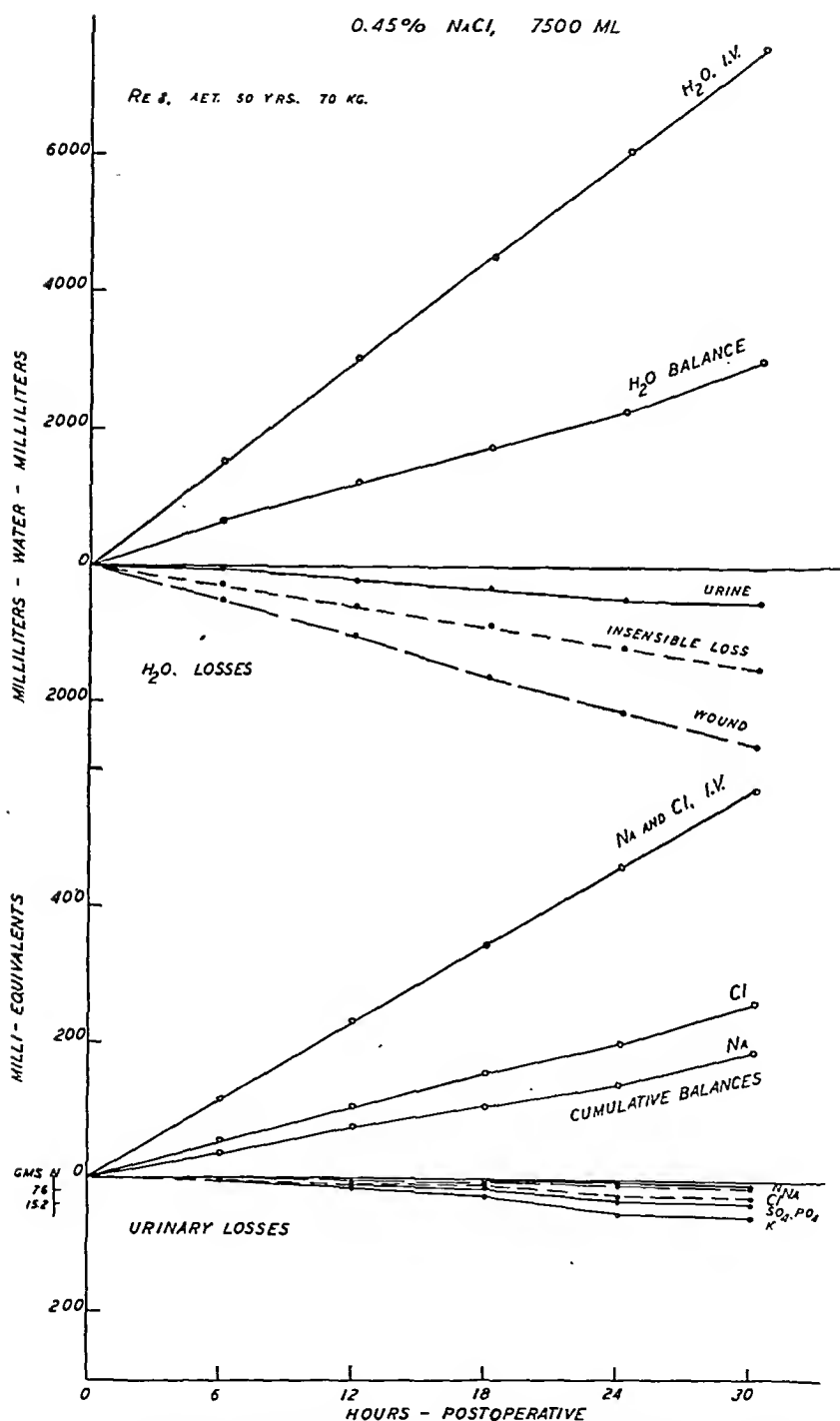


FIG. 5.—Cumulative balances of water and sodium and chloride, and fluid and urinary losses of patient Re., m., No. 562,197, who received 7500 ML. of 0.45% NaCl during 30 hours following operation. An uneventful operation was followed by a prolonged period (12 hours) of hypotension, very low pulse pressure, tachycardia and oliguria. The entire postoperative course was characterized by a very marked transudation from the posterior wound.

SALT SOLUTIONS POSTOPERATIVELY

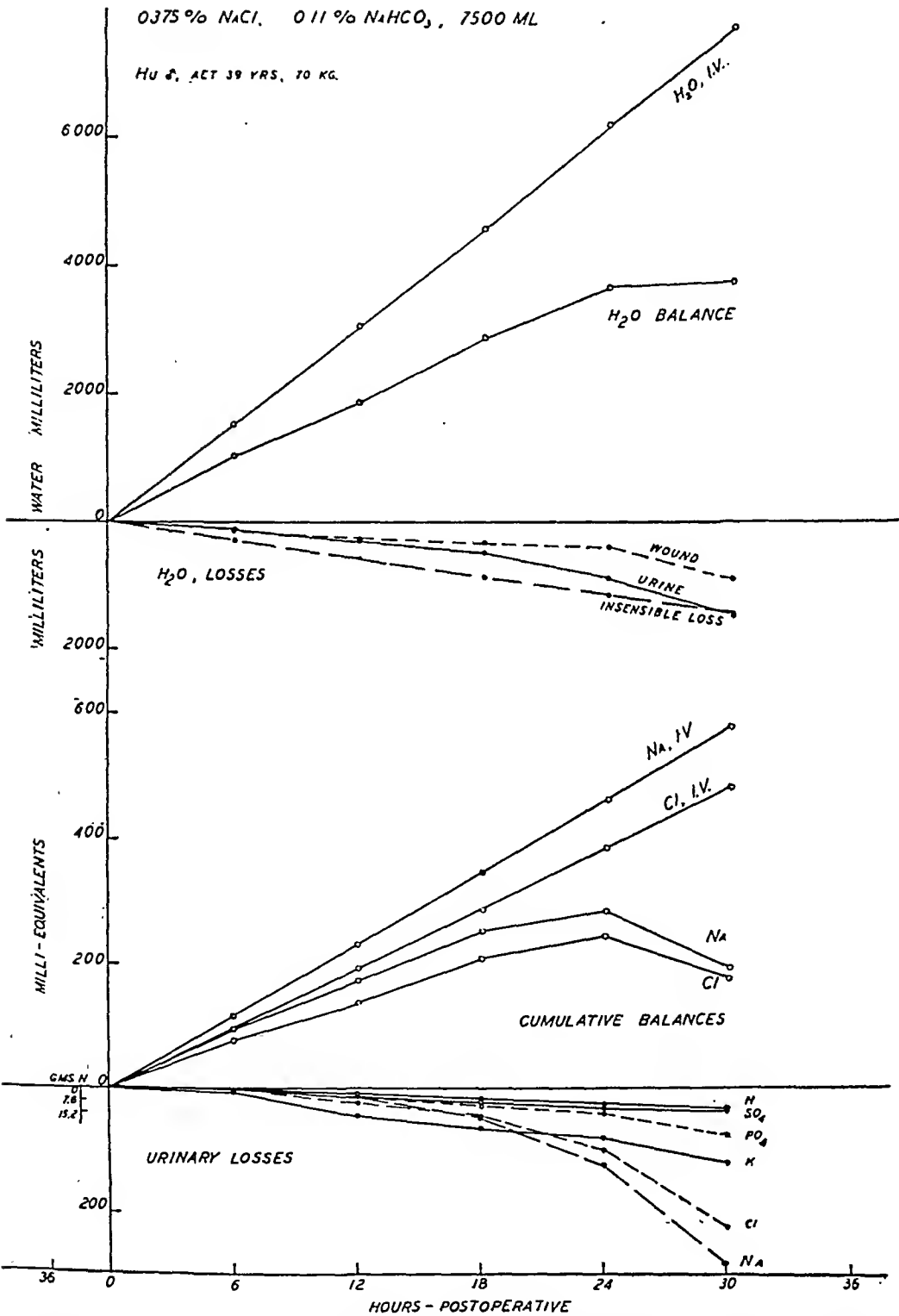


FIG. 6.—Cumulative balances of water and sodium and chloride, and fluid and urinary losses of patient Hu., m., No. 568,596, who received 7500 Ml. of 0.38% NaCl plus 0.11% NaHCO<sub>3</sub> during 30 hours following operation. Mild hypotension developed during the operation, 60/40. The postoperative course was satisfactory.

The loss from wounds is small, in contrast to the patients receiving 0.45 per cent NaCl. At the end of 48 hours, the patient had reduced the sodium load to  $-10$  mEq., the chloride load to zero, and the water load to 2,770 ml.

Table IV divides the patients into a so-called physiologic salt group (physiologic sodium or physiologic chloride) and an hypotonic group. The loads at 30 hours are computed as per cent of in-put. Basic differences are

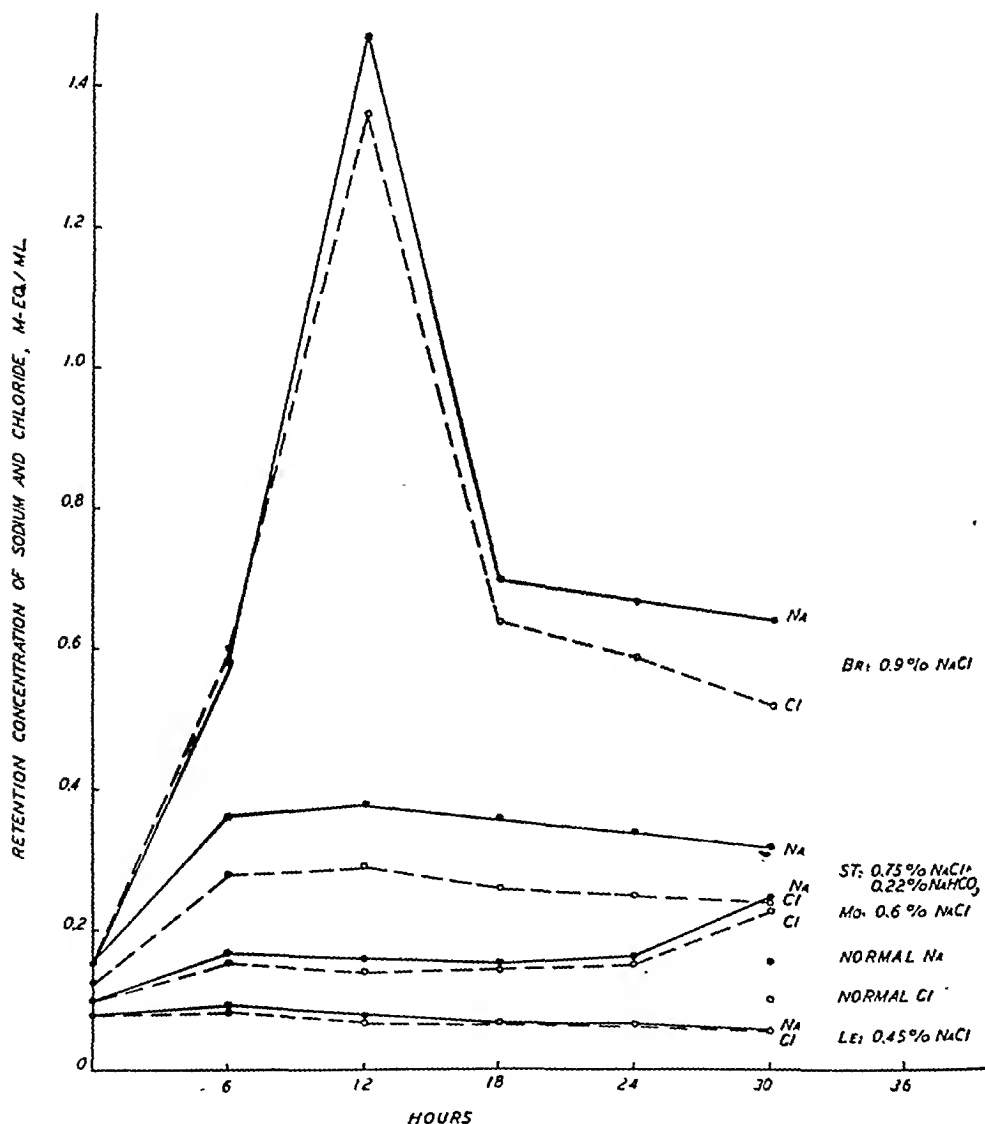


FIG. 7.—Calculated retention concentrations of sodium and chloride, mEq. per ml. of four patients receiving isotonic salt solution, adjusted isotonic salt solution, isotonic chloride and hypotonic salt solutions, plotted against time after operation in hours.

found in the marked retention of salt with respect to water in the physiologic salt group, and the retention of water over salt in the hypotonic group.

Figure 7 describes the same findings graphically by plotting retention concentrations of sodium and chloride against time in hours. The graph reveals no tendency of the human kidney to convert the volume of infused fluid to a retained concentration of 0.102 mEq. per ml. as found by Wolf<sup>24</sup> for t'

# SALT SOLUTIONS POSTOPERATIVELY

dog, and again emphasizes the inability of the human kidney to concentrate urine so well as the dog.

DISCUSSION.—Contrary to animal experiments, surgical patients cannot be considered to have a zero salt and water load at the start of the operation. Varying degrees of hydration and salt balance must exist, especially if the patient has been prepared for operation by Miles' regimen, as in the present series. However, the retention concentrations of Patient Br indicate strongly that there is little need for 27 Gm. of salt. The average loss of blood at these operations indicates a need of about 2 Gm. of salt. The urine, at best,

TABLE IV  
THIRTY-FOUR LOADS OF SODIUM, CHLORIDE AND WATER, PER CENT OF IN-PUT

Patient	Infusion	Sodium Per Cent	Chloride Per Cent	Water Per Cent
Br ♂	0.9% NaCl.....	63	52	15
St ♀	0.75% NaCl+0.22% NaHCO <sub>3</sub> .....	74	67	35
Vo ♂	0.75% NaCl+0.22% NaHCO <sub>3</sub> .....	27	23	5
Mo ♂	0.6% NaCl.....	46	43	19
Average, isotonic solutions.....		53	46	19
Hu ♂	0.38% NaCl+0.11% NaHCO <sub>3</sub> .....	34	37	50
Le ♂	0.45% NaCl.....	26	26	34
Sm* ♀	0.45% NaCl.....	16	19	30
Re ♂	0.45% NaCl.....	33	46	40
Average, hypotonic solutions.....		27	32	39

\* Sm received 80% of the infusion.

excretes 7 Gm. of the excess; the losses from the anterior and posterior wounds accommodate an additional 5 Gm. There remains an excess of 13 Gm. of salt which serves only to embarrass a water balance already strained by the exigencies of operation and sequelae.

The hypothesis that the excretion rate of a substance is ordinarily proportional to load is untenable in the case of these surgical patients. The normal kidney is able to concentrate chloride taken orally to the extent of 0.29 to 0.33 mEq. per Ml.<sup>25</sup> In spite of heavy salt loads, no patient approximated this value. As a result of increasing salt load and increasing hypertonicity of the extracellular compartment, osmotic relationships can only be maintained by a shift of water from intracellular to extracellular space. Loads of salt created by the isotonic solutions require a transfer of approximately two liters of intracellular water within 30 hours after operation. The edema, a symptom of postoperative salt intolerance, may result not so much from the retention of water with salt as from the shifting of water from the intracellular to the extracellular space. It is unknown how much dehydration the cells can undergo before function breaks down and ceases. The brain cells are especially sensitive to change and the disorientation so often seen in cases of salt intolerance may be a symptom of this fluid shift.

## SUMMARY AND CONCLUSIONS

Salt solutions of various composition and tonicity were administered to men and women undergoing major surgical operations. The rates of excre-

tion of the urinary constituents were determined. Losses of sodium, chloride and water from the posterior and anterior wounds were estimated by use of weighed dressings. Cumulative balances of water, sodium and chloride were calculated.

1. The injection of "isotonic sodium chloride" solutions was attended by an average retention of 53 per cent of the sodium, 46 per cent of the chloride, and 19 per cent of the water 30 hours after the operation. Such retentions of salt indicate a withdrawal of approximately two liters of fluid from the intracellular compartment in order to maintain isotonicity.

2. The infusion of hypotonic solutions resulted in the average retention of 27 per cent of the sodium, 32 per cent of the chloride, and 39 per cent of the water during the same postoperative period. Extra water is thereby provided for excretory function of skin and lungs, and the intracellular compartment is not involved.

3. The human kidney, under the conditions of these experiments, does not elect to guard a "physiologic saline" solution.

4. If intravenous infusion is indicated in the postoperative care of the surgical patient, hypotonic solutions, 0.45 per cent NaCl, or better, 0.38 per cent NaCl plus 0.11 per cent  $\text{NaHCO}_3$ , should replace the "isotonic" solutions commonly in use.

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# METABOLIC ALTERATIONS FOLLOWING THERMAL BURNS

## V. THE USE OF WHOLE BLOOD AND AN ELECTROLYTE SOLUTION IN THE TREATMENT OF BURNED PATIENTS\*

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IN RECENT YEARS there has been some controversy concerning the best means of combating shock in severely burned patients. Although there are a number of methods which apparently suffice to tide patients over the critical 48-hour period following an injury, their influence on the subsequent course of the patients is not well understood. In 1944, Moyer, Coller, Iob, Vaughan and Marty<sup>1</sup> employed various forms of therapy in the treatment of shock caused by a burn involving 80 per cent of the body of anesthetized dogs. They pointed out that the dogs treated with whole blood intravenously and a sodium chloride-bicarbonate solution orally survived longer than dogs who were treated with plasma. Because their experiments were limited to the early shock period it seemed desirable to evaluate the effect of these various forms of treatment in less severely burned animals and to note the changes which occurred during the convalescent period. The results of such a study were reported in a previous publication.<sup>2</sup> They tended to show that the anemia which occurred during the convalescent period could be prevented if whole blood was given early.

It is the purpose of this communication to compare a group of patients who were treated with plasma with another group who received whole blood intravenously and an electrolyte solution orally. The changes observed in various blood constituents and in the elimination of water and salt will be briefly discussed.

### METHODS

The patients who are included in this report were studied after being admitted to the Metabolic Ward. The organization of the Metabolic Ward and the facilities have been previously described.<sup>3</sup> The methods of determining the cell volume (hematocrit), plasma protein and albumin concentration have been previously stated.<sup>4</sup> The plasma chloride concentration was determined by the method of Van Slyke as modified by Wilson and

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Ball,<sup>5</sup> the plasma CO<sub>2</sub> content by the method of Van Slyke and Neill,<sup>6</sup> the blood urea was done as described by Van Slyke and Cullen,<sup>7</sup> and the non-protein nitrogen concentration determined by a modification of the method of Gentzkow.<sup>8</sup> Sodium and potassium were determined on the aqueous solution of the ash, digestion and ashing carried out according to the method of Cullen and Wilkins,<sup>9</sup> with the ashing temperature maintained at 450°-500° C. Sodium was determined by the method of Butler and Tuthill's<sup>10</sup> modification of Barber and Koltoff, and potassium by the method of Shohl and Bennett as modified by Salit.<sup>11</sup> The blood was drawn with a minimum amount of stasis, employing greased syringes, and clotting was prevented by the use of heparin. All samples for CO<sub>2</sub> content were drawn and separated under oil and again heparin was employed as the anticoagulant. Blister fluid taken from A. T. was aspirated by inserting a sterile needle through normal tissue into the bottom of the blister. The fluid was removed with an oiled syringe containing heparin. A small number of red blood cells which were present in the samples were removed by centrifugation before the clear fluid was analyzed.

The electrolyte solution\* contained the following amount of salts per liter of distilled water: 6.10 Gm. sodium chloride; 0.20 Gm. calcium chloride; 0.20 Gm. potassium chloride; 0.07 Gm. sodium phosphate (monobasic); 0.05 Gm. magnesium chloride; 2.38 Gm. sodium bicarbonate; and 2.0 Gm. dextrose. The approximate amount of this solution given over the first 48 hours was equal to 15 per cent of the patient's body weight. The quantities of blood and plasma employed were prescribed according to the severity of shock, depth and the surface area involved, and the size of the patient.

## RESULTS

For the convenience of presentation and discussion, the patients are divided into mildly burned (5-15 per cent of the surface area); moderately burned (15-35 per cent); and severely burned patients (35-100 per cent).

In Figure 1 the changes in the hematocrit, the extent and type of burn, and the therapy in six mildly burned patients are presented. I. S., Case 2, and D. C., Case 3, received no intravenous therapy, while varying amounts of plasma were given to the remaining cases. It is interesting to note that in all of these patients, with the possible exception of D. C., the hematocrit fell to levels below normal. Hemoconcentration was not evident except in the case of D. C. The plasma protein concentration in these six patients remained above 6.0 Gm. per 100 cc. but in many instances the initial plasma albumin concentration of 4.0 to 4.5 Gm. per 100 cc. subsequently fell to around 3 Gm. per 100 cc. The plasma chloride concentration and blood urea levels were within the normal range while in most cases the hemoglobin levels and red blood cell counts paralleled the change in the hematocrit (on several occasions the hemoglobin showed a slightly more marked fall than did the

\* Kindly furnished in concentrated form in sterile ampoules by Sharp & Dohme, Philadelphia, Pa.

hematocrit). The burn was caused by clothing catching on fire in all instances except that of C. L., Case 5, who was burned during an explosion (flash burn).

Figure 2 shows the alterations in the hematocrit in five moderately burned patients who were treated with plasma intravenously. The hematocrit again showed a significant decrease below the normal during the convalescent phase and the hemoglobin showed a decrease as great or slightly greater than the hematocrit. Hemoconcentration was evident only in Cases 8 and 11 (Fig. 2). The plasma protein concentration, as a rule, was above 6 Gm. per 100 cc., but in H. S. and M. M. it fell to 5.5 Gm. during the first week post-burn and then rose slowly towards the normal. In L. S. it decreased gradually to 4.5 Gm. per 100 cc. on the third day post-burn. The plasma albumin concentration decreased in all of the patients and in M. M., H. S. and L. S. it reached 2.7, 2.8 and 2.5 Gm. per 100 cc., respectively, when the total protein concentrations were at their lowest level. The blood urea concentrations remained normal in all of these cases with the exception of L. S. This five-year-old patient was burned when her clothing caught fire and, although therapy was instituted promptly, she became anuric shortly thereafter and remained so until death on the fourth hospital day. She had a previous history of nephritis and it was felt that the renal shut-down was in a great part due to the preëxisting disease. Various solutions were given intravenously to this patient (10 per cent glucose, one-sixth molar sodium lactate, and blood) in an attempt to increase the urinary output of the kidneys, but without avail.

Figure 3 shows the alterations in the hematocrit that occurred in four mildly and moderately burned patients treated with an electrolyte solution orally. In three patients whole blood was also administered. In J. J., Case 14, blood was not given initially because the patient was seven months pregnant and was *Rh-negative*. About 30 hours after being burned a premature baby was delivered, but in spite of this and a fairly severe burn, the patient's convalescence was quite uneventful. She did receive several subsequent transfusions of *Rh-negative* blood.

In these cases the hematocrit showed no appreciable decrease, the blood urea concentration remained within a normal range throughout, and the plasma protein and albumin concentrations paralleled quite closely the changes seen in the patients treated with plasma. In the first two patients, normal values were encountered throughout, but in J. J. and B. T. the plasma protein concentration dropped to 5.03 and 5.12 Gm., respectively, but rose gradually to 6.00 Gm. per 100 cc., and remained at that level, or above, for the remainder of their hospital stay. The plasma albumin concentrations in these two patients, likewise, showed a fall to around 2.3 Gm. per 100 cc. when the plasma protein concentration was low.

In most of the patients presented in the first three figures, the plasma albumin concentration fell after the burn, reaching its lowest value somewhere between three to ten days. It later increased, but rarely did it reach the

METABOLISM FOLLOWING BURNS

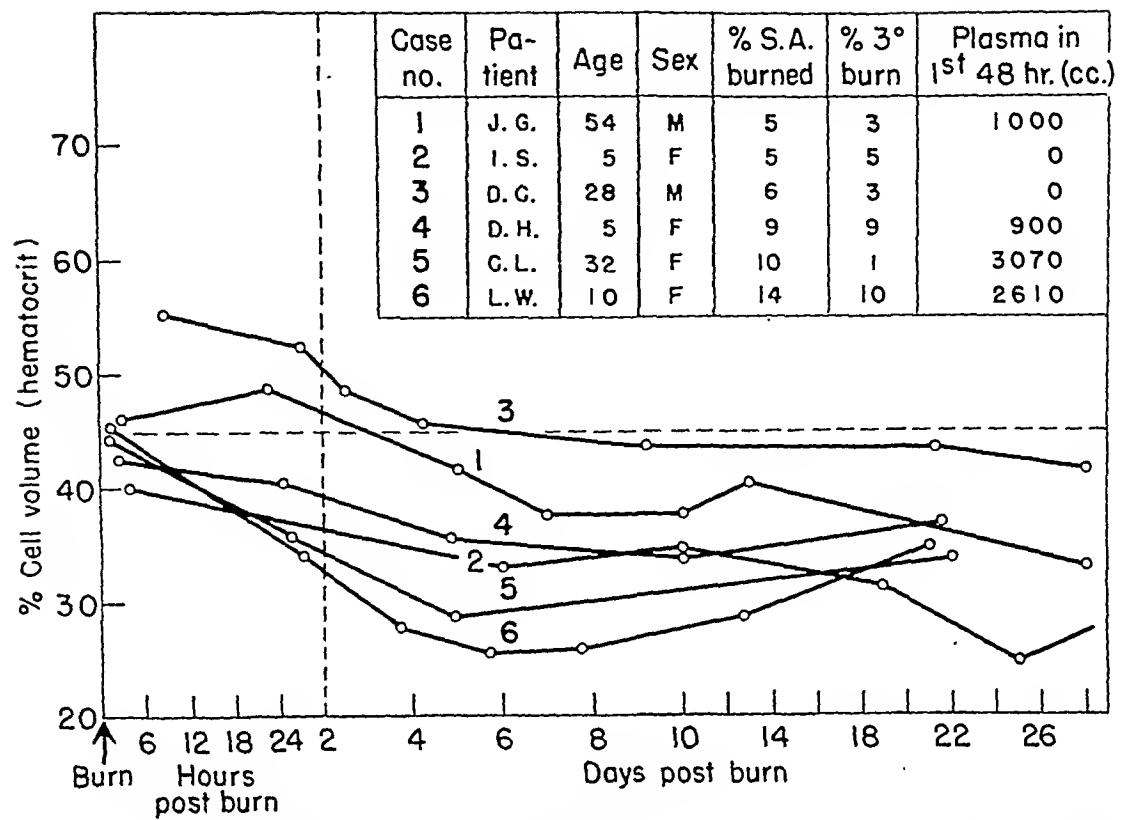


FIG. 1.—Hematocrit alterations in mildly burned patients receiving plasma or no intravenous therapy.

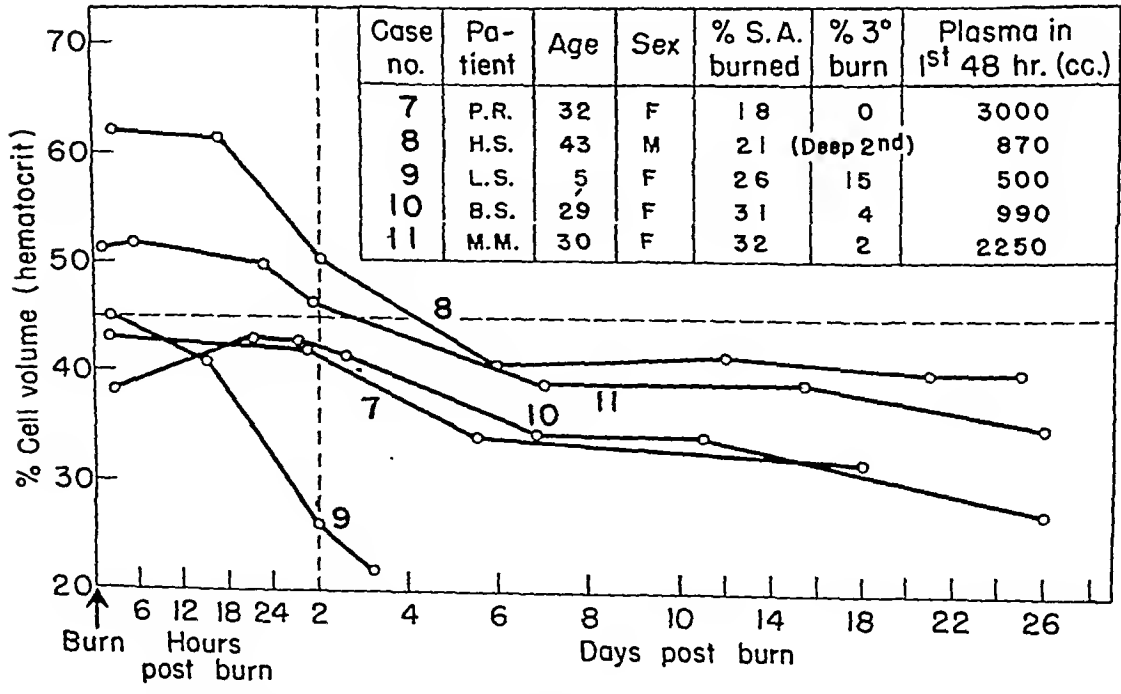


FIG. 2.—Hematocrit alterations in moderately burned patients treated with plasma.

value noted on admission, even though the plasma protein concentration had returned to normal. Thus, the plasma globulin values showed an increase while the plasma albumin concentration was lowered, and this condition often persisted for weeks.

Hemoconcentration of a significant degree was evident in only three of the 15 patients, as determined by an increase in the hematocrit.

In Tables I, II and III, the treatment given and the chemical alterations noted in three severely fire-burned patients who received plasma are presented. It can be seen from the findings in these three patients that at the time of death the hematocrit and the plasma protein and albumin concentrations had decreased below the normal. While hemoconcentration occurred, it did not parallel the severity of the patients' burns. The nitrogenous waste products were well cleared from the blood in Cases C. W. and F. H., and partially removed in A. T.

TABLE I

C. W. 42-YR.-OLD. ♂ BURNED BY FIRE. TOTAL BURN 32%; 3°-BURN 25%						
Time Post-burn	Hematocrit	Plasma Protein Gm./100 Cc.	Plasma Albumin Gm./100 Cc.	Blood Urea Mg./100 Cc.	Plasma Chloride mEq./liter	Treatment
3.5 hrs.	49.6	6.43	4.05			900 cc. plasma
10 hrs.	51.5	6.40			102.3	885 cc. plasma
16.5 hrs.	60.0					600 cc. plasma
34 hrs.	58.5	5.80	3.10	35		1060 cc. plasma
2.25 days	51.5	5.30	2.90			1165 cc. plasma
5 days	44.0	5.30		30		—
7 days	38.2	4.60	2.40	28	98.0	4610 cc. total plasma given

TABLE II

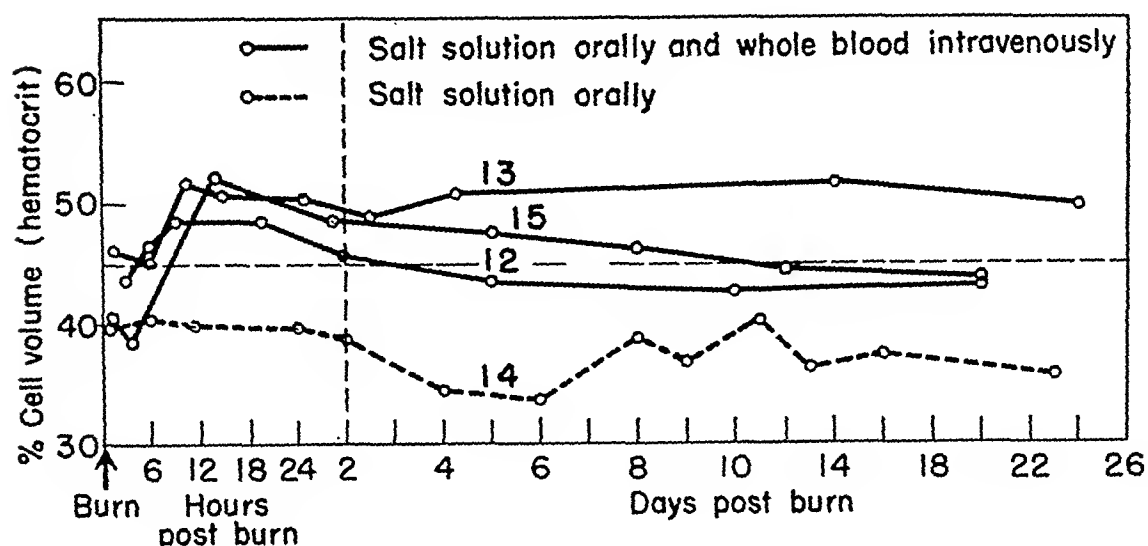
A. T. 48-YR.-OLD. ♂ BURNED BY FIRE. TOTAL BURNS 45%; 3°-BURN 35%						
Time Post-burn	Hematocrit	Plasma Protein Gm./100 Cc.	Plasma Albumin Gm./100 Cc.	Nonprotein Nitrogen Mg./100 Cc.	Plasma Chloride mEq./liter	Treatment
7 hrs.	66.0					1500 cc. plasma
1 day	70.4	6.89			98.8	3035 cc. plasma
2.33 days	51.6	5.27	3.21	82	101.0	3000 cc. plasma
4 days	51.6	5.70	2.79	93	93.6	—
6 days	41.8	5.35	2.79	82	94.4	7535 cc. total plasma given
9 days	37.9	5.24	2.42	90	103.8	
12 days	36.2	5.56	2.44	70	102.8	

TABLE III

F. H. 17-YR.-OLD. ♀ BURNED BY FIRE. TOTAL BURN 64%; 3°-BURN 32%						
Time Post-burn	Hematocrit	Plasma Protein Gm./100 Cc.	Plasma Albumin Gm./100 Cc.	Blood Urea Mg./100 Cc.	Plasma Chloride mEq./liter	Treatment
2 hrs.	59.5	6.60	4.19	37		
1 day	43.4	5.06	3.00			4240 cc. plasma
2 days	36.0	6.01	3.10	47	106.0	1500 cc. plasma
3 days	39.4	5.30	2.90	27		—
5 days	34.2	5.19	2.75		96.2	5740 cc. total plasma given

In Tables IV, V and VI, the alterations in the blood chemistry which occurred in three patients burned by fire and treated with whole blood intravenously and an electrolyte solution orally are presented. The decrease in

the hematocrit did not occur until after a month although whole blood was only given during the first 24 hours after the burn. There was a fairly marked decrease in the total plasma protein and albumin concentration in all three cases, but this in no way seemed to interfere with the recovery of patients M. D. and W. L.



Case no.	Pa-tient	Age	Sex	% S.A. burned	% 3° burn	Solution given in first 48 hr. (cc.)	
						Electrolyte solu. orally	Blood I. V.
12	J. J. J.	46	M	12	0	9000	450
13	T. A.	14	M	14	1	8000	800
14	J. J.	25	F	25	18	10000	0
15	B. T.	3	F	35	0	3000	500

FIG. 3.—Hematocrit alterations in mildly and moderately burned patients treated with an electrolyte solution orally.

Edema was present in these three patients but was decreasing by the third to fourth day post-burn and was not clinically evident after the sixth day. The patients (Tables I, II and III) who were treated with plasma showed just as marked an accumulation of fluid which persisted somewhat longer.

Figures 4, 5, 6, 7 and 8 show the total fluid intake and urinary output in five of the aforementioned cases. It can be observed that in the mildly and moderately burned cases (J. J. J., W. L., and M. D.) a much higher per cent of the total fluid ingested was eliminated than in the more severely burned patients (A. T. and R. J.). The findings in these five cases were quite comparable to the other patients in whom similar studies were made. Thus, the records of the patients studied show that following a burn, larger amounts of fluid are consumed than would be normally. In those who ultimately recover the elimination of the excess fluid is readily accom-

TABLE IV

W. L. 11-YR.-OLD. ♂ BURNED BY FIRE. TOTAL BURN 28%; 3°-BURN 12%

Time Post-burn	Hemato-crit	Plasma Protein Gm./ 100 Cc.	Plasma Albumin Gm./ 100 Cc.	Nonprotein Nitrogen Mg./ 100 Cc.	Plasma Chloride mEq./ liter	Plasma CO <sub>2</sub> Content Vol. %	Plasma Amino-acid Mg./ 100 Cc.	Treatment
2.5 hrs.	57.0	6.18	4.03	30	97.6	47.5	3.78	500 cc. blood
17 hrs.	58.0	4.66	2.79	18	106.2		5.34	
23 hrs.	59.6							500 cc. blood (5000
29.5 hrs.	60.0							cc. of the electrolyte
39 hrs.	58.9	4.58	2.46		97.5		6.17	solution plus 1000 cc.
3 days	52.8						4.78	of water taken first
5 days	46.2	5.11	2.53	33	93.4	56.6	3.92	day, and 2000 cc. of
9 days	43.8	5.91	2.84	24	97.2	61.6		the electrolyte solu-
12 days	45.5				96.4	58.0	3.39	tion plus 1000 cc. of
18 days	41.2	6.66	3.29	37	104.1	59.3	3.65	water on second day)
30 days	31.7	6.16	3.44		104.2			

TABLE V

M. D. 26-YR.-OLD. ♀ BURNED BY FIRE. TOTAL BURN 32%; 3°-BURN 20%

Time Post-burn	Hemato-crit	Plasma Protein Gm./ 100 Cc.	Plasma Albumin Gm./ 100 Cc.	Nonprotein Nitrogen Mg./ 100 Cc.	Plasma Chloride mEq./ liter	Plasma CO <sub>2</sub> Content Vol. %	Sodium mEq./ liter	Treatment
1.5 hrs.	51.3	7.12	4.47	21	100.9			1520 cc. blood (6000
29 hrs.	59.2	5.29	3.24	26	100.9	49.0		cc. of electrolyte so-
2.25 days	57.2	5.47	3.41	18	99.1			lution during first 24
4 days	49.8	5.03	2.79	25	91.2	49.0		hrs., and 2000 cc. of
6 days	48.8	5.42	2.85	25	88.4	66.0		electrolyte solution
8 days	47.0	5.91	2.61	30	87.3	70.8		given on second day)
11 days	44.2	6.10	2.59	25	98.6	55.1	135:2	
14 days	45.9	6.76	2.89	29	94.3	56.0		
19 days	44.4	7.26	3.01	32	98.6	63.3	135:2	
22 days	41.3	7.18	3.14	31	93.6			
29 days	28.3		2.69	22	91:7	61.3		
42 days	34.4	6.63	3.07	26	100.1	62.0	139:2	
60 days	38.9	6.45	3.37	24	102.3			
74 days	40.7	6.55	3.51		99.0			
90 days	40.8	7.09	4.01	31	102.4			

TABLE VI

R. J. 42-YR.-OLD. ♂ BURNED BY FIRE. TOTAL BURN 47%; 3°-BURN 35%

Time Post-burn	Hemato-crit	Plasma Protein Gm./ 100 Cc.	Plasma Albumin Gm./ 100 Cc.	Nonprotein Nitrogen Mg./ 100 Cc.	Plasma Chloride mEq./ liter	Plasma CO <sub>2</sub> Content Vol. %	Plasma Amino-acid Mg./ 100 Cc.	Treatment
2.5 hrs.	59.8	6.99	4.77	26	101.2	47.7	5.90	470 cc. blood
8 hrs.	76.1				106.8	46.5	6.67	460 cc. blood
13 hrs.	75.6				105.9		6.89	250 cc. blood
27 hrs.	72.4	4:14		65	113.9	52.5	4.70	530 cc. blood
34 hrs.	63.6	3.99			117.6			
52 hrs.	62.1	4.40		52	112.5	63.2	5.07	
75 hrs.	54.3	4:28	2:12	64	112.2	55.6	4.61	350 cc. conc. plasma
81 hrs.	46.2	4.08			112.1			
84 hrs.	47.6							
4 days	47.0	4.72			111:2		5.53	550 cc. blood (Pt.
5 days	46.3	5.20	2.24	75	111.1		4.34	took 9000 cc. of the
7 days	43.5	5:52		158		40.6	6.50	electrolyte solution
								on the first day, and
								3000 cc. on the sec-
								ond day post-burn)

METABOLISM FOLLOWING BURNS

plished, but in the cases that die there seems to be an inability of the body to properly rid itself of water.

It is difficult to tell how much fluid was lost in the exudate from the burned area, as perspiration, and through the lungs, but it was felt that the loss through these sources was not greater in the severely burned patients than in those with moderate burns. In many instances, where an extensive

FIG. 4

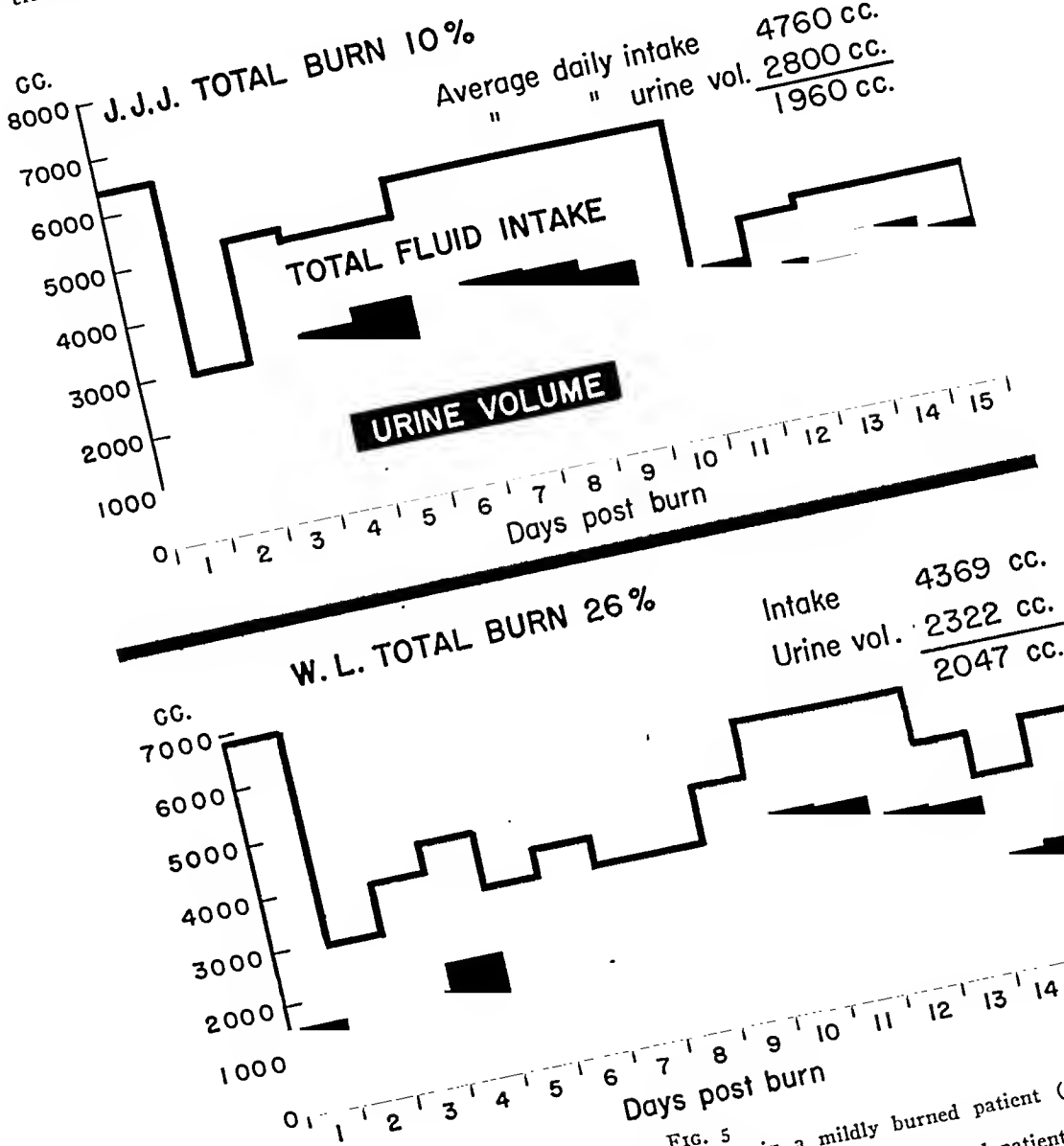


FIG. 4.—Total fluid intake and urine excretion in a mildly burned patient (no third-degree burn).  
FIG. 5.—Total fluid intake and urine excretion in a moderately burned patient (12% of surface area involved by third-degree burn).

third-degree burn was present the skin was of a leathery consistency and very little fluid could penetrate through. Thus, while it is not possible to tell for certain it seems likely that patients A. T. and R. J. retained much greater amounts of fluid than did the other cases that survived.



The analysis of the blister fluid obtained from A. T., and the time post-burn that each specimen was removed, are shown in Table VII.

The daily loss of electrolytes from the exudate was measured in ten of

FIG. 6

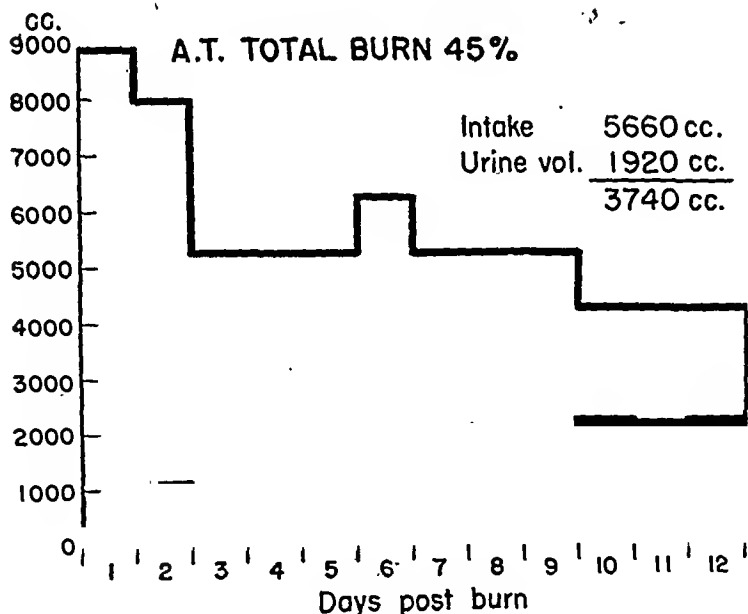
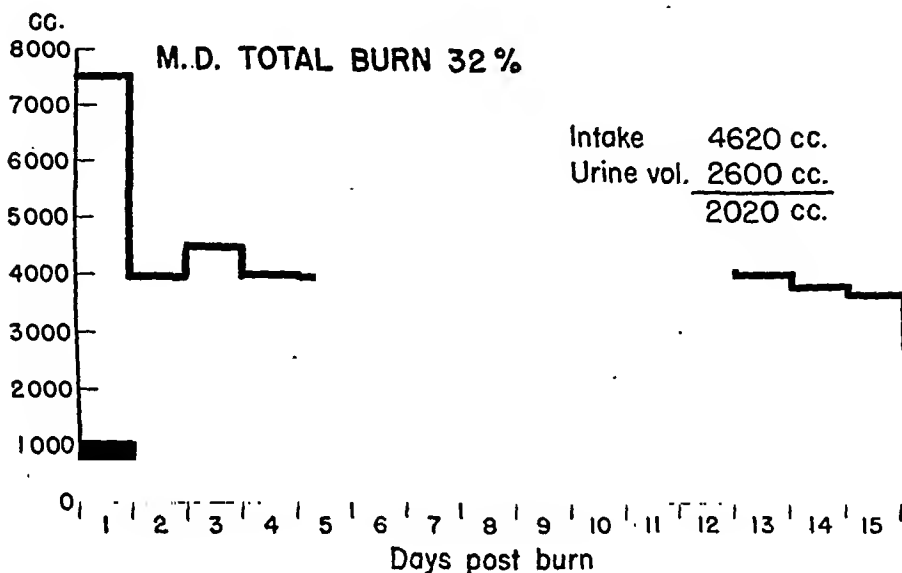


FIG. 7

FIG. 6.—Total fluid intake and urine excretion in a moderately burned patient (20% of surface area involved by third-degree burn).

FIG. 7.—Total fluid intake and urine excretion in a severely burned patient (35% of surface area involved by third-degree burn).

the patients as well as the intake and urinary output of sodium, potassium and chloride and will be reported in a later publication. It seems evident from this work, however, that the external loss (urine, feces and exudate) of the various electrolytes studied parallels somewhat the elimination of

water and is a great deal less in the severely burned patient than in the mildly or moderately burned cases.

**DISCUSSION.**—From the work presented and previous experimental work<sup>2</sup> it would seem that the giving of whole blood early prevents or alleviates the anemia which occurs so commonly during convalescence from a burn. The various causes of the anemia seen during the convalescent period have been previously discussed,<sup>2</sup> and it was brought out that a state of overhydration may, in many instances, contribute to a decrease in the hematocrit, and also in the plasma protein concentration. It is felt that Case 9 (L. S., Fig. 2) is an example of this. This patient was given large amounts of fluid which she was unable to excrete and since a relatively small amount of blood and plasma was administered, the precipitous fall noted in her hematocrit and in the plasma protein concentration was for the most part due to a dilution of these constituents rather than to a diminution in the actual amount of blood cells and protein.

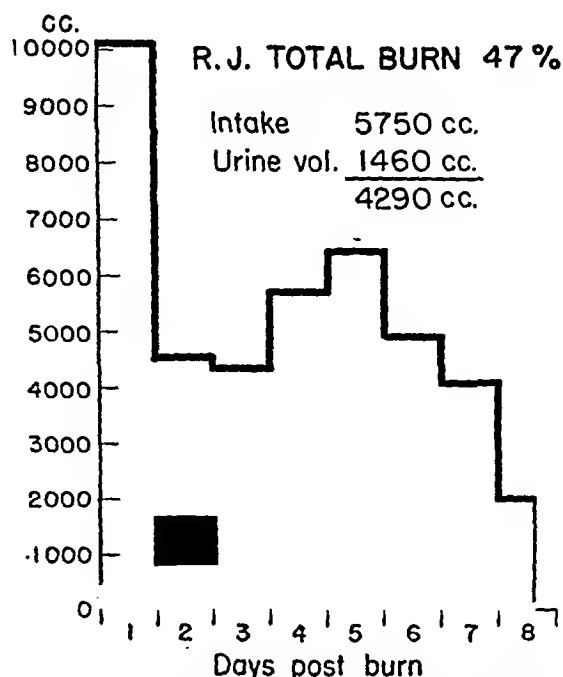


FIG. 8.—Total fluid intake and urine excretion in a severely burned patient (35% of surface area involved by third-degree burn).

From the experimental work of Rosenthal,<sup>12</sup> Allen,<sup>13</sup> and Warren, Merrill and Stead,<sup>14</sup> and the clinical experience of Fox,<sup>15</sup> it appears that solutions containing sodium salts are beneficial in the treatment of shock. One of our cases (J. J., Case 14) who was quite severely burned was treated only with an electrolyte solution by mouth during the period of shock. The remaining cases received whole blood intravenously and an electrolyte solution orally, as advocated by Moyer, Coller, Iob, Vaughan and Marty.<sup>1</sup>

Although this series of cases is much too small to permit definite conclusions regarding the effect of various types of therapy on the mortality rate, it does appear that the judicious use of whole blood and an electrolyte solution is an effective means of combating shock in burned patients.

Patients with a severe or moderate burn accumulate large amounts of fluid in the traumatized area regardless of the type of therapy employed to combat shock, but it has seemed that the edema diminishes more rapidly when salt solutions were used than when large amounts of plasma were administered. When plasma is given much additional protein is provided but there is no evidence to show that the plasma protein in itself is of more than temporary value in these burned patients. In some of our patients who received large amounts of plasma, low protein values were encountered and in three of the severely burned patients these low values persisted until death. Low plasma

protein levels were also encountered in the patients treated with smaller quantities of citrated whole blood and an electrolyte solution orally, but these were usually seen when the edema was decreasing and subsequently the protein levels rose toward normal. There is no reason to suspect that the giving of whole blood would be more beneficial than plasma in the prevention of hypoproteinemia, but the evidence does indicate that the giving of plasma does not prevent the decrease in the plasma protein concentration.

It has been generally believed that by increasing the blood osmotic pressure by the addition of plasma proteins, especially albumin, shock could be prevented or corrected. In peripheral circulatory collapse resulting from a burn, however, the albumin is rapidly lost, and, thus, gives only a transient beneficial effect. The analysis of the blister fluid taken from A. T. (Table VII) shows that the greatest part of the protein present in such fluid is albumin. These results are somewhat comparable to those of McIver,<sup>16</sup> and of Harkins,<sup>17</sup> except that the figures for protein and nonprotein nitrogen in this case are higher (probably due to a more severe burn). McIver<sup>16</sup> reported that the concentration of sugar (87 mg. per 100 cc.) paralleled that found in the blood, and stated that the calcium concentration (15.3 mg. per 100 cc.) was slightly elevated. Previous studies on sodium and potassium concentrations have not, as far as we are aware, been reported. These values tend to show a slight increase in the first 27 hours above the normal plasma concentrations.

TABLE VII

ANALYSIS OF BLISTER FLUID (A. T., 48-YR.-OLD, ♂ 45% OF BODY BURNED)

Time Post-burn	Total Protein Gm./100 Cc.	Albumin Gm./100 Cc.	Sodium mEq./liter	Potassium mEq./liter	Chloride mEq./liter	Nonprotein Nitrogen Mg./100 Cc.	CO <sub>2</sub> Vol. %
27 hrs.	5.51	3.76	150.0	6.05	101.6	74	
4 days	5.06	3.15			98.8	102	55.8
6 days	4.59	3.21	136.5	5.18	96.2	65	

Thus, most of the osmotic effect of albumin or of the entire plasma proteins is transient and when it is lost through the capillary walls into the injured area it must continue to exert an osmotic pull towards the injured tissues because of the protein which has then accumulated in that region.

Since much of the administered protein is lost in patients in shock resulting from a burn, it would seem as though the best treatment would be: (a) in giving a substance which exerted an osmotic effect and would not be lost; (b) in rendering the injured capillaries less permeable, if such were possible, or; (c) by increasing the tissue tension to a point where fluid would no longer tend to leave the capillaries in excessive amounts.

Danielli's<sup>18</sup> experiments tend to show that the edema which occurs when a salt solution alone is perfused through an animal's extremity can be slowed by adding blood cells (especially platelets) to the solution. The perfusion experiments of Zweifach<sup>19</sup> show that there is apparently a substance derived from the surface of fresh plasma which has a "coating effect" and, thus,

tends to decrease the capillary permeability. In view of this work it would appear as though whole blood or plasma would have some advantage over a salt solution alone, but apparently since capillary permeability cannot be quickly or completely restored to normal it would seem logical to give an electrolyte solution so that tissue tension would be increased.

During the past several years it has been noted that burned patients rarely die during the so-called period of shock (first 48 hours). It does seem, as has been previously suggested,<sup>2</sup> that an inadequate or delayed therapy will result in a diminished urine flow and that the patients who ultimately die (third to 14th day) excrete small amounts of urine during the first several days. Such patients (A. T. and R. J.) also subsequently show a failure to excrete water and salts in a normal fashion. Thus, if toxic products are formed following a burn, the ill effects produced would be dependent upon the amount of such products present (severity of third-degree burn) and the ability to remove them (kidney and liver function). It would, therefore, seem that if the mortality rate of the severely burned patient (over 30 per cent of the body surface area involved by a third-degree burn) is to be reduced, prompt and adequate therapy should be employed so that an excellent urine volume is assured. In our experience it has been difficult to get a good urine flow subsequently if a good volume is not excreted during the first day. R. J. was given 350 cc. of concentrated plasma (10 Gm./100 cc.) three and one-half days after the burn in an attempt to increase his urinary flow, but the per-minute rate of excretion was not altered. Subsequently distilled water and later whole blood was given for the same reason, but at no time did the rate of urine excretion increase as it would have done in a normal individual.

From the results presented it can be seen that wide differences occurred in the hematocrit during the period of shock which could not be correlated with the extent and depth of the burn. Some patients (Cases 3 and 8) with mild to moderate burns showed higher hematocrits than individuals with severer burns (Cases 9 and 10). On the other hand, some severely burned patients have shown relatively slight changes above the so-called normal value (45). The hematocrit, therefore, is frequently a poor guide to the type and amount of treatment that is necessary, especially since it is influenced by a preëxisting anemia, the rate and number of cells destroyed or trapped from the general circulation at and following the time of injury, and because the normal hematocrit varies quite widely. The first-aid method proposed by Harkins<sup>20</sup> for the control of burn shock (*i.e.*, 50 cc. of plasma for every per cent the body is burned) seems to be more logical, but, again, some patients (Cases 2, 4, 5, 7, 10, 14 and 15) need therapy and yet because of a preëxisting anemia whole blood would appear to be more beneficial than plasma.

In giving treatment for the first 48 hours, therefore, it seems logical to give approximately 50 cc. of blood to adult patients for every per cent the body surface area is burned or to give it in amounts equal to from 1-5 per cent of the patient's body weight in kilograms. In employing the electrolyte

solution it seems desirable to give a slightly hypotonic solution (two-thirds to three-quarters strength in order to increase the rate of urine excretion) in amounts equal to about 10–15 per cent of the patient's body weight during the first two days following the burn. Since little experience has been had with this form of treatment no absolute rules should be employed, but the treatment should be modified depending on the severity and the degree of the burn and the size and response of the patient. When shock is not severe treatment may be given relatively slowly, but if the patient shows evidence of peripheral vascular collapse, therapy should be carried out rapidly until the condition has improved, and urine is being excreted. It should be remembered that the larger quantities advocated above are comparable to giving amounts of fluid which are roughly equal to an individual's total extracellular fluid volume (plasma and interstitial fluid volume), hence, when such amounts are employed, additional liquids and foods should not be given, or should be permitted only in small quantities for the first two days, as this would lead to an excessive fluid intake. If it seems desirable, dextrose can be added to the fluid to provide calories (or some form of protein could be added to the electrolyte solution). In severely burned patients it has seemed that high caloric and protein intakes are better avoided initially.<sup>3</sup> It has been our practice recently to give 800 to 1,000 calories in the form of dextri-maltose daily for the first several days and to supplement vitamins two to five times the normal daily requirement. In mildly burned patients very little blood, plasma or salt solution may be necessary and, thus, a normal diet can often be instituted early.

In most of the patients, excessive hemoconcentration was not encountered when whole blood was given providing an adequate amount of salt solution was employed. In R. J. the hematocrit rose to 76.1, but the patient did not seem to have any ill effects from this rise. This marked increase was apparently due to the giving of blood while the patient was not absorbing adequate amounts of the electrolyte solution due to vomiting.

It has been pointed out<sup>21</sup> that the viscosity of blood is dependent on many factors and that the accumulation of various plasma protein fractions play just as important a rôle as does the addition of red cells. Thus, it seems that if whole blood and an electrolyte solution are simultaneously employed it should not result in a great change in blood viscosity, because as the cell volume increases there is a decrease in the protein fraction. In fact, if large amounts of plasma are given and the albumin fraction is lost, while globulin and fibrinogen are retained (due to the relatively small molecular weight of albumin as compared to globulin and fibrinogen) the blood viscosity might be increased. However, here again, the small increase in the amounts of globulin and fibrinogen would probably not alter the viscosity appreciably because, while they have a much higher viscosity coefficient than does the red cell, the decrease in the cell to plasma ratio produced by the administration of plasma would tend to compensate for the increase in viscosity due to the protein fractions.

When the hematocrit is definitely elevated (55 to 60, or above), the patient's blood pressure is low and little urine is being excreted, we see no reason why plasma should not be given instead of whole blood if it seems to be desirable. In these studies no ill effects have so far been noted if the hematocrit has risen above these levels, but there seems to be no advantage in having an hematocrit of 60, or above, and possibly there is some danger. By the addition of red cells more oxygen might be carried to the tissues and hence anoxia prevented, but it probably is not wise to increase the proportion of cells too much or the beneficial effect will be overcome due to stasis and a slowing of the circulation. Therefore, if hemoconcentration is not excessive it probably would be preferable to give whole blood intravenously and an electrolyte solution orally; but if the hematocrit rises to 60 or above, plasma or a concentrated albumin solution should probably be temporarily substituted for blood. Since several patients have seemingly been taking fluids well by mouth and after two to five hours have vomited, it would seem that where this condition exists the intravenous administration of the electrolyte solution should be temporarily resorted to.

#### CONCLUSIONS

1. The alterations seen in the hematocrit and in other blood constituents following a burn have been discussed.
2. The effect of various forms of therapy on the blood chemistry has been presented.
3. From this study it would appear that the early administration of whole blood plus an electrolyte solution orally to burned patients is an effective method of combating shock, and that this form of therapy will alleviate the anemia which is usually seen during the period of convalescence.
4. It is felt that the hematocrit cannot be employed as a reliable guide to the amount and type of fluid necessary for treating burned patients.

We are very much indebted to Dr. E. Muntwyler, Professor of Biological Chemistry, Long Island College of Medicine, Dr. F. A. Collier, Department of Surgery, University of Michigan, and Dr. C. A. Moyer, Director of Surgery, Eloise Hospital, for their helpful suggestions and criticisms, and to Mary Allison, Georgiène Eberly, Richard Iwata, Catherine McKay, Jean Reed, Lindley Stout and William Sugiyama for their technical assistance.

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# THE RATIONALE OF WHOLE BLOOD THERAPY IN SEVERE BURNS\*

## A CLINICAL STUDY

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INTRAVENOUS THERAPY is so well-established in the treatment of burns there is no longer reason to question its value, but there remains some question as to the best fluid to use. In 1923, Underhill demonstrated the value of sodium chloride solutions in the treatment of burns and, since 1938, blood plasma has been used on a large scale and has proved of value; recently, the publications of Rosenthal,<sup>1</sup> and Fox,<sup>2</sup> have renewed interest in electrolyte solutions.

The purposes of this paper are (1) to call attention to the red blood cell deficit in the burn patient soon after the burn has been received; and (2) to offer clinical evidence that whole blood may be given advantageously to severely burned patients in the presence of so-called hemoconcentration.

Clinicians have observed that many burn patients given plasma in adequate amounts will show by the fourth or fifth day a moderate to severe anemia. Harkins<sup>3</sup> points out that Schrievers found in experimental studies in burns on rabbits an early reduction in the plasma volume accompanied by a decrease in the total circulating red cell mass. The excellent research of Moyer, Coller, Job, Vaughan and Marty<sup>4</sup> demonstrated that in the severely burned dog defibrinated whole blood was more effective in controlling burn shock than was plasma, especially if it was given in conjunction with orally-administered sodium chloride-bicarbonate solution.

## THE RED BLOOD CELL DEFICIT IN BURNS

Between 1941 and 1944 we had collected a considerable body of blood volume data on severely burned patients. The initial blood volume determinations were made before any fluid had been given intravenously and at 18- to 24-hour intervals for four to five days. Our original interest in blood volume determinations in burn patients was aroused by doubt as to the reliability of estimates of plasma loss when calculated by formulae proposed by Elkinton, Wolff and Lee,<sup>5</sup> and by Harkins<sup>6</sup>; this will be discussed in a later paper. We were further stimulated to reexamine this blood volume data by the studies of Moyer, *et al.*, on the value of whole blood therapy in experimental burns. When calculations from these blood volume data were made for

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This study was carried out under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the Medical College of Virginia.



total circulating red cell mass in burn patients, it was found that in some of them there existed, soon after the burn had been received, a serious deficit in red cell mass. In nine calculations taken at random from the blood volume data of some of the more seriously burned patients it was found that the red blood cell deficit averaged around 40 per cent of the total volume in deficit. This is shown graphically in Chart 1. It is evident that there may exist in the severely burned patient a serious red blood cell deficit and that this can only be corrected by the administration of whole blood. When only plasma was administered a serious secondary anemia rapidly developed.

We have confidence in the validity of these data on the red blood cell deficit in the severely burned patient for two reasons: (1) When intravenous fluid therapy consisted only of plasma, and redeterminations of the total mass of circulating red blood cells were made at intervals during the first 72 to 96 hours, there seemed to be little change in the size of this mass. If any change occurred, it was in the direction of a further decrease; and (2) if only plasma was given, and the initial data showed a smaller than normal circulating red cell mass, when the blood volume was returning to normal around the 72nd hour there occurred regularly a moderate to severe secondary anemia, which persisted until red blood cells were given.

Other than a deficit in the red cell mass soon after the burn is received the cause of the early anemia in burn patients has not been disclosed by any studies made by us. We do not believe intravascular hemolysis is responsible for the major portion of this red cell deficit because in many patients there was little or no staining of the plasma with free hemoglobin; we are of the opinion that the red cell deficit is due in the main to sludging or trapping of large masses of red blood cells in the capillaries in and adjoining the burned area. This view is supported by the work of Moritz<sup>7</sup> who found quantities of iron in the skin of experimentally burned animals, amounting in some cases to around 30 per cent of the total circulating hemoglobin.

It might be stressed that hematocrit data do not necessarily indicate the extent of the anemia in burns, especially when plasma and red cells are lost in disproportionate amounts into the burned area. Further, some of the deficit in red cell mass, especially in children and women in our series, may have been the result of a preëxisting anemia. This view is supported by the findings of Dr. T. Stanley Meade,<sup>8</sup> who has found a moderate to severe secondary anemia in approximately 50 per cent of the children examined by him in our local health clinics.

#### CLINICAL STUDIES OF WHOLE BLOOD THERAPY IN SEVERELY BURNED PATIENTS

The main purpose of this study was to evaluate whole blood transfusion\* in the management of burn shock in the severely burned patient. Since our studies on red cell deficit in the burn patient (mentioned above) indicated that without blood volume data the hematocrit reading might give no indication of

\* By whole blood transfusions we mean "citrate blood"; 50 cc. 5 per cent sodium citrate is used as anticoagulant in each 500 cc. whole blood.

red cell loss, it was decided to give whole blood transfusions to this series of patients regardless of hematocrit readings. We were encouraged to do this, despite the height of some hematocrit readings, by the report of Moyer, *et al.*, that scalded animals with hematocrit readings of 75 to 80 per cent could be given massive transfusions of defibrinated blood, and that these were compatible with life. Accordingly, whole blood transfusions were given in some cases when the hematocrit readings were as high as 65 to 67 per cent.

The general plan of a clinical experiment was to treat the patient's burn by pressure dressings and to give intravenous whole blood infusions of 500 to 1,000 cc. every six hours for the first 48 hours, along with enough saline and other fluids to keep up a urinary output of 50 to 100 cc. per hour. Every effort was made to have the patient take fluids by mouth rather than by the intravenous route. Fluids were given in the form of water, soft drinks, milk, or fruit juices. This required special nursing care, which was provided in most instances. No attempt was made to give large amounts of sodium salts, orally or intravenously, but with each whole blood transfusion 8 Gm. of sodium bicarbonate was given. Some patients who took fluids best in the form of soft fountain drinks, such as coca-cola, were allowed to have them. All patients were typed and given only type specific blood. At the suggestion of Dr. Philip Levine,<sup>9</sup> all female patients were given *Rh*-negative blood until it could be demonstrated that this was unnecessary. For children one to five years of age the six-hourly infusions of whole blood were usually limited to 150 to 200 cc.; in all burned patients every effort was made to give whole blood to the amount necessary to keep the hemoglobin level above 100 per cent during the first four days of therapy. Penicillin, usually 100,000 units daily, was given to all patients.

In this series of 32 burn patients there have been three deaths: The first, an eight-year-old Negro child, was found in a burning house in which her mother and sister perished. The child was brought to the hospital about four hours after having been burned and was in a state of severe shock; the blood pressure being unobtainable. There were third-degree burns of approximately 60 per cent of the body surface, with severe burns of the face. When the bladder was catheterized no urine was obtained. The initial hematocrit was 67 per cent. She was given during the next eight hours approximately 1,000 cc. of whole blood and 1,000 cc. of saline. In four hours 470 cc. of urine was obtained. The child died following generalized convulsive seizures about eight hours after admission. At catheterization of the bladder after death 210 cc. of urine was obtained. The nonprotein nitrogen was 26 on admission and 40 shortly before death. It would appear that in this apparently hopelessly burned child, admitted in a state of severe shock, whole blood therapy at least resulted in a return of renal blood flow to well above that usually found at the shock level. The second death is that of a 57-year-old Negro male, with approximately 80 per cent body surface involved by third-degree burns. He had been found lying in a bed that had caught fire, and had been apparently stuporously drunk at the time. On admission, he was

unconscious, with a blood pressure of 70/50. He was given during the next four hours approximately 2,000 cc. of whole blood and equal quantities of normal saline, but died four hours after admission. The third death occurred in an 11-year-old burned child, 26 days after admission. This patient's treatment and course will be commented on in detail (Case 1).

#### CASE REPORTS

**Case 1.**—(Fig. 1, Chart 2): C. P., age 11, was admitted to the Medical College Hospital, January 5, 1945, after having suffered a severe burn. While standing in front of a bonfire his clothing became ignited. The flames were finally smothered by blankets. On admission to the hospital, there was a deep burn extending from the nipple line over the entire body down to the ankles. Sedation was secured with intravenous morphine gr.  $\frac{1}{6}$ . The burned areas were cleaned with soap and water and dressed according to the pressure dressing technic. Fluid therapy was given as shown in Table I. During the first 24 hours the patient received 2,500 cc. of blood and adequate fluids by mouth so that a urine output of approximately 2,000 cc. was secured for that period. Reference to Chart 2 illustrates that this patient received whole blood transfusions despite the presence of what is considered severe hemoconcentration. During the second 48 hours he received an additional 1,000 cc. of whole blood and adequate fluids by mouth to maintain a good urinary output. The child was quite ill during the first four days of hospitalization, but by the 96th hour showed marked improvement. He was then able to take all necessary fluid by mouth and maintained daily a good urinary output. Penicillin was given every fourth hour, 10,000 to 15,000 units. The first dressing was done on the 12th hospital day, at which time the photograph shown in Figure 1 was made. At this dressing it was observed that sloughing would take place of the full-thickness of the skin from the ankles to the axillae. At this time, however, the child was in remarkably good condition. He was given whole blood transfusions to the amount of 500 cc. about every third day after the first four days. The hemoglobin levels, which were taken daily, never fell below 82 per cent, and generally were above 90 per cent. The plasma protein, while it was 5.4 per cent on the fourth day, steadily rose, so that by the tenth hospital day it was 6.2 per cent, at about which level it remained. In addition to the blood transfusions a daily intake of approximately 100–120 Gm. of protein was maintained. Although we despaired of ever securing enough skin for grafting, the child's condition appeared hopeful until January 29, the 24th hospital day, at which time he became irrational. Blood chemical studies were all within the normal range, the nonprotein nitrogen being at no time above 46 mg. per cent. It was noted on January 29 that the blood pressure was rising, and late on that day the readings were regularly 160/110, whereas previously they had been in the range of 110/70. Gradually a comatose state set in, and by January 30 the child could not be aroused. All attempts at plasma, whole blood, sodium chloride or sodium lactate therapy failed to change the condition. Despite every attempt at therapy the child died on January 31, 1945. A postmortem examination was secured. This examination showed the burned skin to involve approximately 60 per cent of the body surface. The autopsy revealed no adequate explanation for the patient's death; since permission for examination of the brain could not be obtained, it is impossible to eliminate an encephalitis or degenerative cerebral lesion as a primary cause of death (see Walker and Shenkin<sup>10</sup>). Sections of the liver and kidneys showed no changes from the normal.

**COMMENT:** This burn patient represents one of the most serious we have treated, and was, indeed, a real test for the efficacy of whole blood transfusions for the management of burn shock. The fact that the child was kept alive for 26 days, with fairly normal levels of hemoglobin, plasma protein and

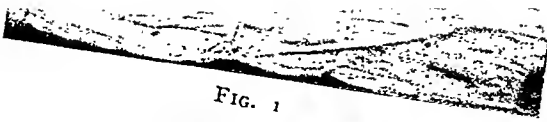


FIG. 1



FIG. 2



FIG. 3



FIG. 4

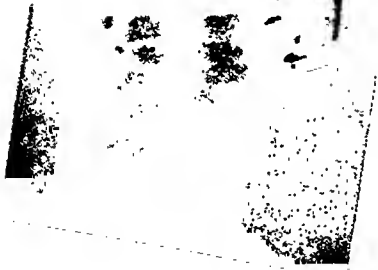
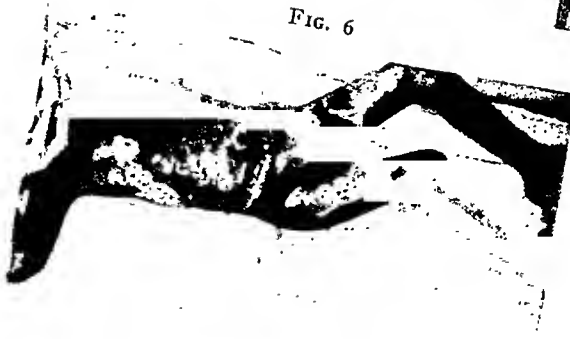


FIG. 5



FIG. 6



- FIG. 1.—Case 1: C. P., taken on first redressing on the 12th hospital day. Full-thickness burns from ankles to nipple line.
- FIG. 2.—Case 2: D. T., illustrating extent and depth of the burns of the legs. Figures 7, 8 and 9 show the extent of the burns in this patient of the left arm, thorax, abdomen and buttocks.
- FIGS. 3 and 4.—Case 3: H. R., illustrating extent of the burns. Photograph taken at first redressing.
- FIG. 5.—Case 4: W. H., taken at first redressing.
- FIG. 6.—Anterolateral portion of the thorax of badly burned child taken at the time of first grafting. The good state of nutrition is to be noted. This child received large and frequent whole blood transfusion at the time of entry.



# WHOLE BLOOD THERAPY IN BURNS

TABLE I  
FLUID BALANCE SHEET FOR PATIENTS DISCUSSED IN DETAIL IN TEXT

Day	Oral			Intravenous	Urine
	Water	Milk	Fruit Juice		
Case 1. C. P.					
1	1600	550	510	2500 blood 2000 saline 1400 water 3 amp. sod. lact. 32 Gm. NaHCO <sub>3</sub>	1735
2	2445	710	215	500 blood 500 saline 2 amp. sod. lact. 8 Gm. NaHCO <sub>3</sub>	1975
3	1730	1040	90	500 blood 1500 saline 1 amp. sod. lact. 8 Gm. NaHCO <sub>3</sub>	1985
4	1420	1640	680		2745
5	1515	2235	680		1625
Case 2. D. T.					
1	1560	....	500	3300 blood 3000 saline 2500 water 2 amp. sod. lact. 32 Gm. NaHCO <sub>3</sub>	1525
2	2370	720	790	2000 blood 2500 water 1000 saline 1 amp. sod. lact. 32 Gm. NaHCO <sub>3</sub>	2010
3	3240	1050	200	500 blood 8 Gm. NaHCO <sub>3</sub>	1795
Case 3. H. R.					
1	1470	....	400	2500 blood 1000 water 1000 saline 2 amp. sod. lact. 24 Gm. NaHCO <sub>3</sub>	1900
2	360	....	250	1500 blood 3000 water 24 Gm. NaHCO <sub>3</sub>	2100
3	1210	200	650	500 blood 8 Gm. NaHCO <sub>3</sub>	1000
4	2460	360	380	3000 saline	1350
Case 4. W. H.					
1	1860	300	660	2500 blood 500 saline 1 amp. sod. lact. 32 Gm. NaHCO <sub>3</sub>	2762
2	1860	360	500	1000 blood 16 Gm. NaHCO <sub>3</sub>	2400
3	1540	450	640	500 blood 8 Gm. NaHCO <sub>3</sub>	1900
4	1280	480	440		1200
5	1430	720	560	500 blood 8 Gm. NaHCO <sub>3</sub>	1300

# BLOOD AND PLASMA DEFICIT IN BURNS

% of burned surface	45%	75%	22%	32%	80%	36%	35%	15%	13%	46%
Hematocrit	59	57	41	44	68	48	48	53	50	57

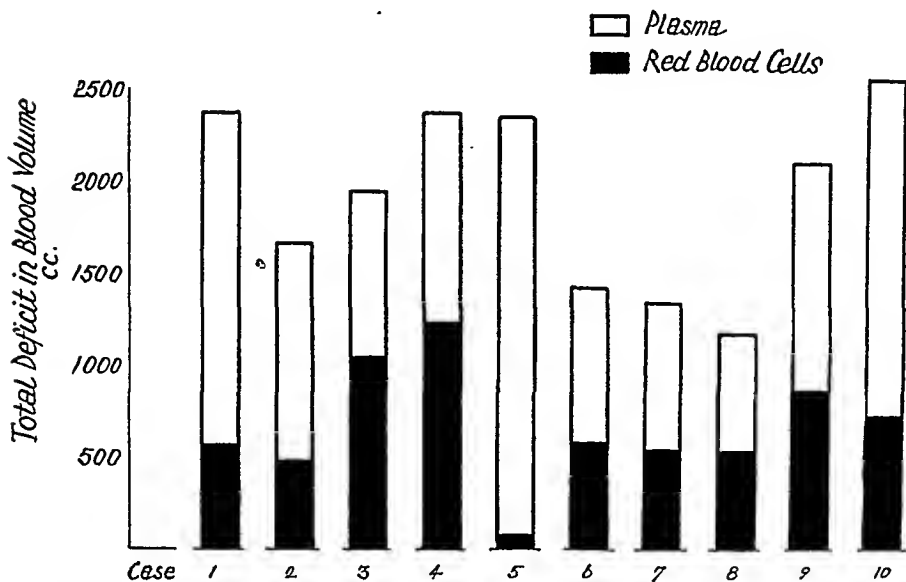
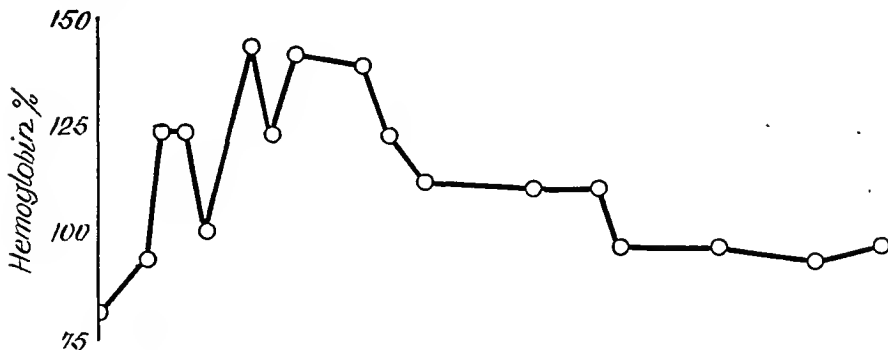


CHART 1.—Diagram illustrating the red blood cell and plasma loss in a series of severely burned patients. Calculations were made on the basis of a normal person having a total blood volume of 80 cc. per Kg., and an hematocrit of 45%. Cases 2 and 5 died on the fourth and fifth days, respectively; the other patients survived. Case 5 was largely a second-degree burn.

Fluid intake	8460	4270	5160	
Urine	1735	1975	1985	
Total protein	5.2%	5.2%	5.4%	5.4%
NPN	38	32	46	43



C.P.

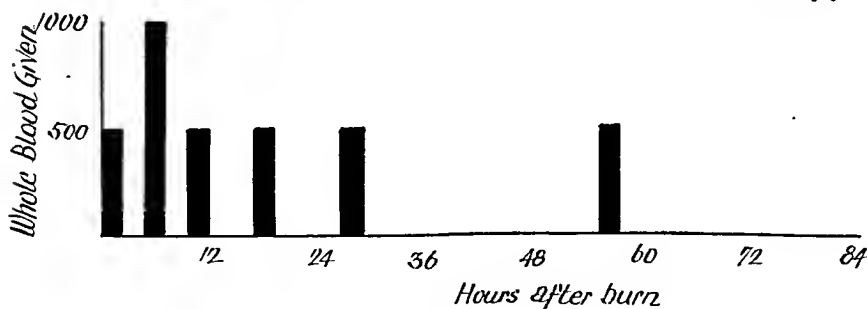


CHART 2.—The treatment and course of Case 1, C.P.

urinary output attest, we believe, to the value of whole blood transfusions in the badly burned patient.

Case 2.—D. T., white, male, age 27, was admitted November 18, 1944. In a fire which totally destroyed an automobile trailer (in which his wife and child perished), the patient suffered severe deep burns of left arm, thorax, trunk, buttocks and legs, as shown in Figures 2, 7, 8 and 9. On admission, the blood pressure was 115/70. Pressure dressings were applied rapidly, and intravenous blood and saline therapy begun. Thirty-three hundred cubic centimeters of whole blood was given during the first 24 hours, and 2,400 cc. during the second day. Whole blood was given in the presence of marked

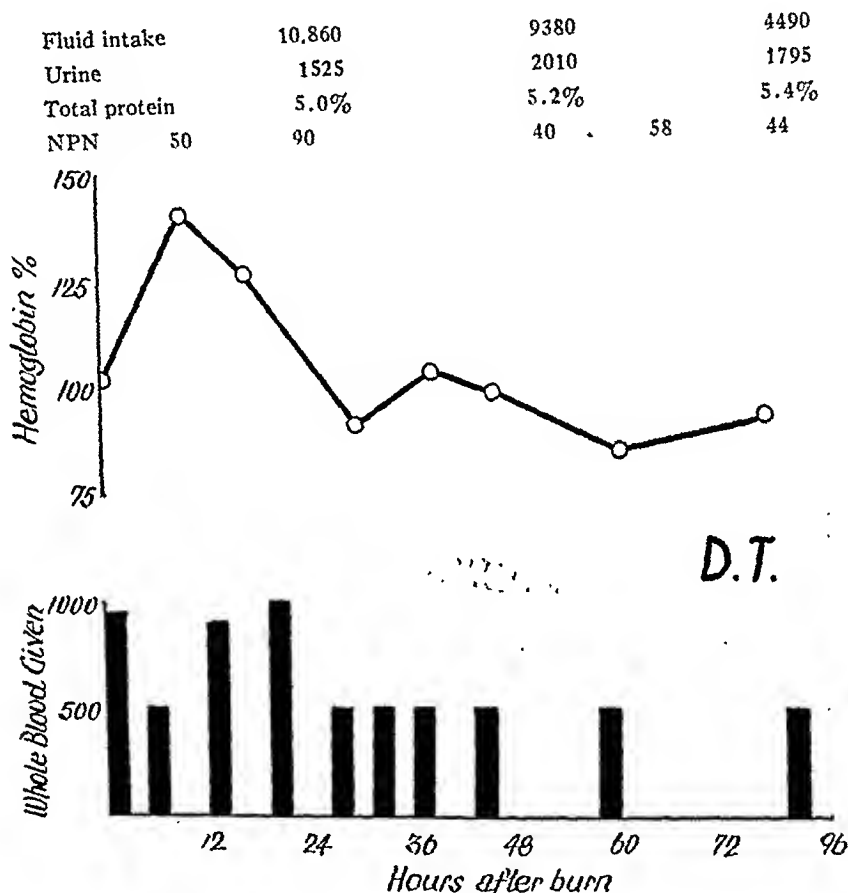


CHART 3.—The treatment and course of Case 2, D. T.

hemoconcentration in this patient (Chart 3). Urine output was good, although the nonprotein nitrogen rose to 90 at the 12th hour, returning to 40 the next morning. Fluids were taken well by mouth, and on the third day a special high protein diet was started which the patient took well. The first redressings were made of the arms and chest on the 14th day, the buttocks and legs five days later. Grafting of the legs was done first on January 2, 1945. It is interesting to note that this extensively burned patient maintained a good hemoglobin level (never below 79 per cent during his six-month hospital stay); this we attribute to his excellent coöperation in taking a special high protein diet daily during his first five months of hospitalization and which will be discussed in a later paper. He was discharged June 3, 1945, after grafting and intensive physiotherapy, able to walk. He will return later for revision of a graft of the left popliteal space.



Fluid intake	6370	5110	2560	6200
Urine	1900	2100	1000	1350
Total protein		5.2%	6.4%	
NPN		80	42	40

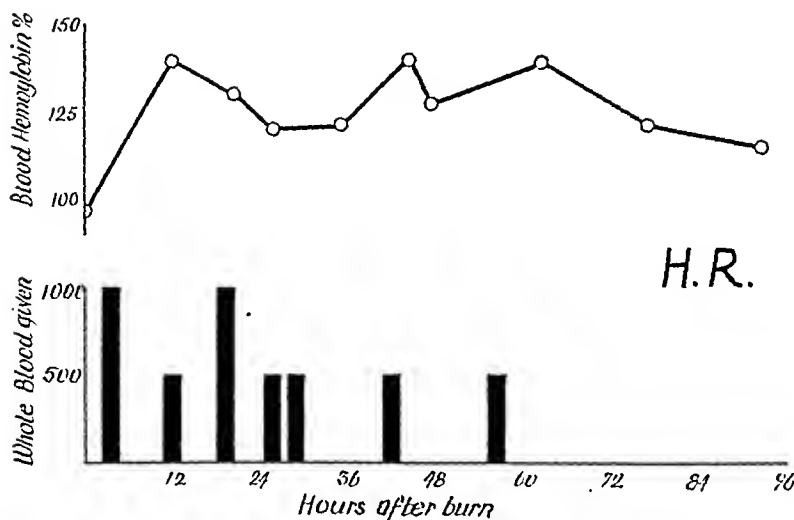


CHART 4.—The treatment and course of Case 3, H. R.

Fluid intake	5820	3700	3130	2200	3210
Urine	2762	2400	1900	1200	1300
Total protein	6.2%		5.8%		6.0%

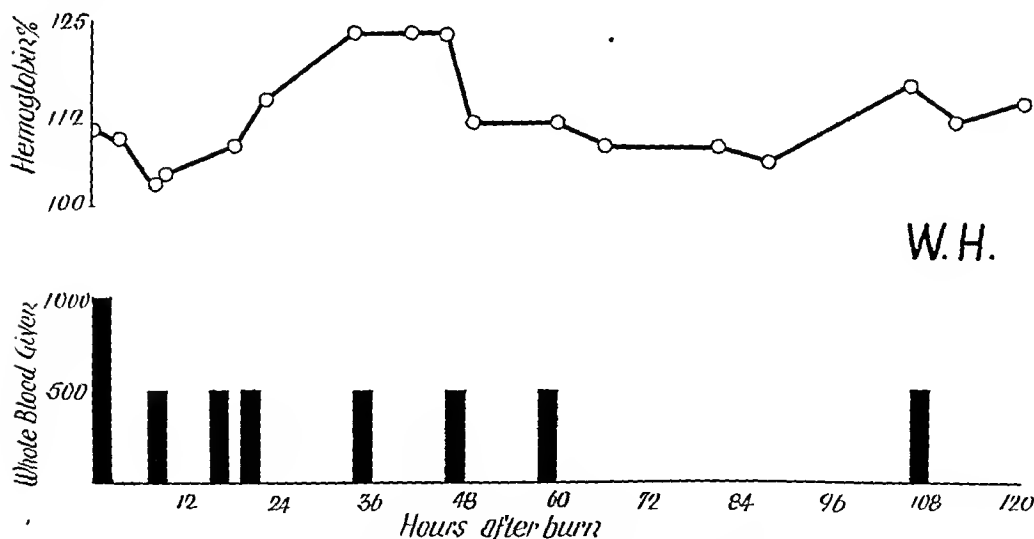


CHART 5.—The treatment and course of Case 4, W. H.

# WHOLE BLOOD THERAPY IN BURNS



FIG. 7



FIG. 8

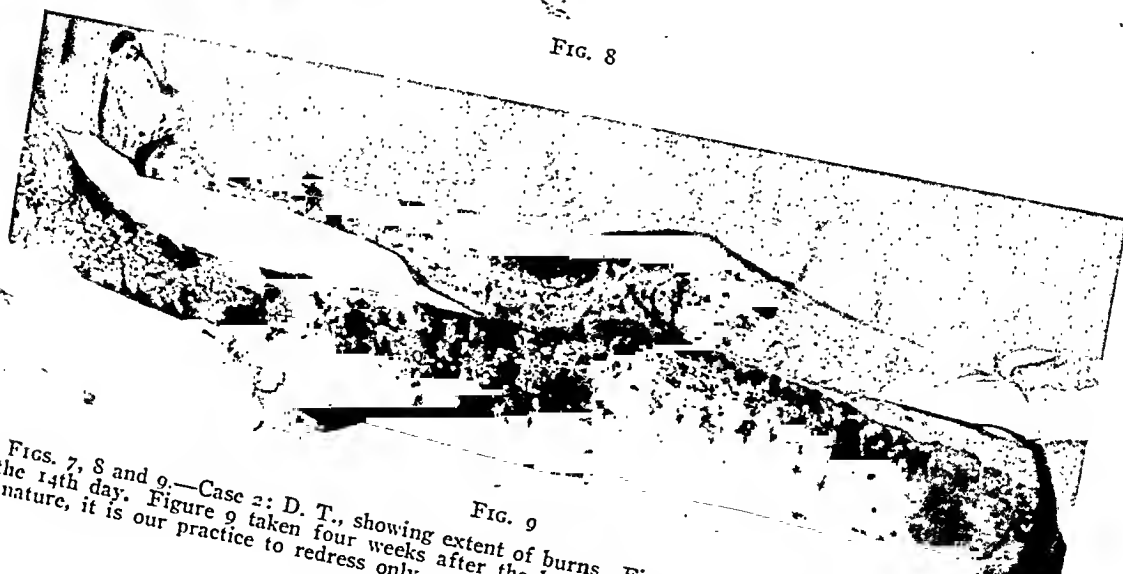


FIG. 9

FIGS. 7, 8 and 9.—Case 2: D. T., showing extent of burns. Figures 7 and 8 taken at first redressing on the 14th day. Figure 9 taken four weeks after the burn had been received. In extensive burns of this nature, it is our practice to redress only small portions of the burned surface at one session.

**Case 3.**—H. R., a 34-year-old Negress, was admitted to St. Philip Hospital January 17, 1945. Her clothes caught fire while she was "throwing kerosene into the stove." Despite extensive burns as shown in Figures 3 and 4, the patient was in good condition on admission. Pressure dressings were applied, and the patient given whole blood transfusions as shown in Chart 4. She took fluids well, and maintained a satisfactory urinary output. Her clinical course was excellent; the first redressings were made on the 14th day, at which time photographs shown in Figures 3 and 4 were made. Although her hemoglobin levels were kept above 85 per cent during the first 29 days of hospital stay, and while she was taking well a special high protein diet, her clinical course was marred by the fact that vigilance relative to diet was relaxed, so that during the second month of hospital stay the hemoglobin dropped to 70 per cent. This was corrected by 1,500 cc. whole blood infusions and resumption of the special diet. Excellent healing occurred of all badly burned parts except the under portions of forearms; these were covered with split-thickness grafts.

**Case 4.**—W. H., an 18-year-old male Negro, who suffered burns of thorax and abdomen, hands and forearms, thighs, scrotum, and penis, was admitted to St. Philip Hospital January 6, 1945. He received his burns as a result of throwing motor oil on an open fire. On admission, the patient was in good condition, and pressure dressings were applied in the ordinary manner soon after entry. He was given 2,500 cc. whole blood during first 24 hours, and 1,000 cc. whole blood the second day (Chart 5). His hemoglobin remained in the neighborhood of 110 per cent after the first 48 hours. Healing of the burned areas was extraordinarily rapid, the photograph shown in Figure 5 being taken on first redressing on the 14th hospital day. Plasma protein levels never fell below 5.8 per cent, and after the 14th hospital day remained above 6.8 per cent. The special high protein diet was given starting on the fourth hospital day. During the first month of treatment the hemoglobin was consistently 100 per cent or above, although no more blood transfusions were given after the fifth hospital day. On February 2, 1945, the penis was covered with a dermatome split-thickness graft and "postage stamp" grafts, cut with the dermatome, were applied to the left thigh. The "take" was 100 per cent. The patient was discharged March 1, 1945, with complete recovery.

#### THE CLINICAL EVALUATION OF WHOLE BLOOD THERAPY FOR BURN SHOCK

##### *The besetting sin of clinical investigation can be preference for argument over observation*

After treating several hundred burn patients, we find it difficult to compare the effectiveness of blood and so-called blood substitutes, one with another. It is, therefore, difficult for us to compare whole blood with plasma in the management of burn shock. For this reason some of the observations cited below concerning the value of whole blood in the initial treatment of the severely burned patient might best be termed "clinical impressions." They should not be construed as detracting from the value of plasma in burn therapy.

(1) *Blood Hemoglobin Levels:* In our experience, if fairly large amounts of whole blood are given to the burn patient during the first 48 hours "masked anemia" is not encountered, whereas in burn patients treated only with plasma this condition occurs frequently. It appears, therefore, that if whole blood is given in adequate amounts during the burn shock period secondary anemia will be prevented. This leads us to believe that secondary anemia in burn patients may be more easily prevented than treated.

(2) *Plasma Protein Levels*: When burn patients are given plasma alone, even in large amounts, it is not unusual to find low plasma protein levels on the fourth or fifth day. This is especially true if the burn is deep and extensive (above 40 per cent). On the other hand, in this series of burns treated with large amounts of whole blood the plasma protein levels were maintained at more nearly the optimum level (Cases 1 to 4). This may be due to improved blood flow through the liver during the burn shock period and, therefore, less liver anoxia in the whole blood treated patients. Stated differently, one of the advantages of whole blood therapy may be the maintenance of the liver in such a state that plasma protein production is carried on in a more nearly normal manner during the initial burn period. It should be remembered, however, that this group of patients received large and frequent transfusions.

(3) *Urinary Output*: As was noted in the detailed case reports, we have found it possible to maintain a good urinary output even when hemoconcentration appeared to be quite marked. It is evident from the nonprotein nitrogen figures that renal blood flow must have been maintained at a level adequate for good renal clearance. Difficulty on this score was encountered with only one patient (Case 5).

Case 5.—A 57-year-old colored female, M. T. [on whom we have previous clinical records indicating that she was suffering from hypertensive cardiovascular disease (B. P. 230/140, retinal changes Grade 3) ], when she received a deep burn of approximately 25 per cent of the body surface on March 1, 1945. She was treated with whole blood infusions totaling 2,500 cc. during the first 48 hours, and maintained a good urinary output for the first three days (1,900, 1,725 and 1,285 cc., respectively). Her hemoglobin levels ranged from 100 to 120 per cent during this time. On the fourth day, when her hemoglobin level was 106 per cent, the blood nonprotein nitrogen rose to 106, and her urinary excretion diminished to less than 600 cc. From then on she was given only approximately 2,000 cc. of fluid by mouth each day. By the seventh day the nonprotein nitrogen had come down to 46, and urinary excretion was good, and remained so.

An attempt should be made to induce the burn patient to take fluids and food (especially protein) *by mouth*, so that it is not necessary to give large amounts of fluid intravenously. The observations of Moyer, *et al.*, emphasize this point forcibly. We have hesitated throughout our studies on burns to employ excessively large amounts of fluid by vein precisely for the reasons pointed out by Moyer. Conscious patients, given expert nursing care, will take adequate amounts of fluid by mouth, especially if given the type of fluid they desire. The first burn patient we treated with plasma in 1939, would take only one particular soft drink but drank six to eight bottles of it each 24 hours for the first two or three days. By letting patients have fluids of their own preference and at intervals according to their wishes, or after quiet but firm insistence by the nurse, it is usually possible to maintain a good urinary output throughout the 24-hour period, but when intravenous fluids are resorted to, one usually finds that good urinary output occurs only during and shortly after the fluid administration.

(4) *Toxemia*: Our clinical impression is that these burn patients treated

with whole blood have shown less "toxemia" than did other patients treated with plasma or gelatine. This can only be an impression. The temperature and pulse curves of the four patients whose records were presented above are: Case 1, C. P., for the first four days rectal temperature ranged between  $100^{\circ}$  and  $102^{\circ}$  F., pulse rate between 90 and 120; Case 2, D. T., for the first four days rectal temperature ranged  $102^{\circ}$  to  $104^{\circ}$  F., pulse rate consistently around 120; Case 3, H. R., for the first four days temperature ranged from  $100^{\circ}$  to  $102^{\circ}$  F., pulse rate 90 to 120; Case 4, W. H., rectal temperature first four days  $100^{\circ}$  to  $103^{\circ}$  F., pulse rate 100 to 110. The respiratory rates of all four patients averaged around 30 for the first four days. It should be recalled, however, that Case 1, C. P., was at times irrational during the first two days and vomited small amounts at intervals during this time. One other patient, a badly burned four-year-old colored child, appeared to be quite toxic during the first four days of therapy.

(5) *Healing of Burns*: This is another problem that defies comparison of one series of burns with another because it is difficult to judge the exact depth of the burn in an individual patient, but, in general, burns caused by actual fire are deeper than those caused by hot water or steam. It may be significant, therefore, that in this series all patients were burned by fire. On the basis of our former experience one would have expected that more or less extensive grafting would be required in many of the patients in the present series; such was not the case.

We realize that no known therapy will convert a full-thickness burn into one that heals satisfactorily without grafting. Nevertheless, in burns with severe destruction of the tissues, which heal without grafting, there are several factors that might act to promote or retard epithelial growth. For example, if in a burned area viable epithelial cells are left at the base of hair follicles or sweat glands, healing may take place by outgrowth from these "hidden islands" if (1) the dressing is left undisturbed for long periods of time; (2) infection does not supervene; and if (3) proper nourishment is available to promote rapid growth in the residual epithelial cells.

We have been pleased with the rapidity with which growth of epithelium has taken place in burned areas that at first appeared of a depth and extent to require extensive skin grafting. We do not wish to overemphasize the importance of adequate amounts of whole circulating hemoglobin in the healing process but only with an adequate circulating red cell mass can oxygen and food, such as amino-acids, be carried to the zone of injury in sufficient quantities. With an inadequate number of red cells, healing cannot be rapid.

(6) *Intravascular Clotting*: An increased incidence of thrombosis in burn patients with hemoconcentration has been feared, and one might hesitate to give whole blood for this reason, but it is interesting to note that in this series of 32 patients, 29 of whom survived, there was no instance of thrombophlebitis or pulmonary embolus clinically recognizable.

Finally, it should be emphasized that whole blood has been used in this

series of patients to determine whether it could be given safely to the burn patient in the presence of moderate to severe hemoconcentration. Our experience indicates that whole blood can be given safely under these conditions.

#### CONCLUSIONS

Blood volume determinations of severely burned patients made soon after the burn had been received indicate a decrease in total circulating red cell mass. It is believed that this initial loss of red blood cells may account for a considerable portion of the "masked anemia" that appears in the post-shock period in many burn patients.

Whole blood infusions have been employed for the management of burn shock in a series of 32 severely burned patients. Whole blood has been given in the presence of marked hemoconcentration. Apparently, whole blood can be given safely to burn patients with hemoconcentration. If adequate amounts of whole blood are given initially in severely burned patients, secondary anemia is regularly avoided.

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# DIRECT FLAP REPAIR OF DEFECTS OF THE ARM AND HAND\*

PREPARATION OF GUNSHOT WOUNDS FOR REPAIR OF  
NERVES, BONES AND TENDONS

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GUNSHOT, shell fragment and other types of wounds may leave large surface defects and extensive, crippling scars of the arm and hand. These can be repaired with direct abdominal and chest flaps, by using the principle of a short, broad pedicle, which will allow complete mobilization and immediate use of the flap. There is rarely any need for delaying or tubing these flaps.

This procedure has been carried out in a large number of patients, and a valuable saving of patient-hospital-weeks has been possible. Whereas, long tubed flaps or delayed flat flaps have been known to require months of preparation, this direct type of flap is prepared in 10-30 minutes, and usually can be detached in 14-20 days. So that, the crippled extremity is freed of its scar by thorough dissection, the flap is prepared accurately. at the same time, the arm is "planted" under the flap, and in 2-3 weeks the arm or hand can be detached from the abdomen and the wound closed. It is soon ready for use, or for any necessary deep work on bone, nerve or tendon.

Bone, nerve and tendon repairs cannot be accomplished successfully through dense scar, because the results of these operations can only be as good as the surface healing. When deep repairs are attempted through excessive scarring, the wounds may break down, and wire, foil, screws, plates and bone grafts may be lost. The procedure outlined here is of marked importance in the preparation of many areas for necessary orthopedic or neurosurgical repairs.

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\* This article was to have been presented before the Annual Meeting of the American Surgical Association, May, 1945.



A



B



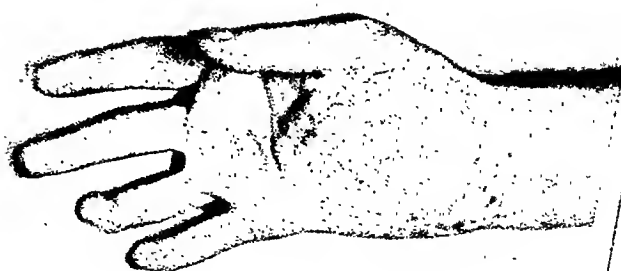
C



D



E



F

FIG. 1.—A to F.—Multiple shell fragment wounds of hand with resultant fibrosis. Widespread dissection with removal of shell fragments encountered. Repair with direct flap detached in 18 days.





"Surface healing can be only as good as the deep blood and nerve supply. Wounds that are excessively fibrotic, and have a diminished blood supply, often cannot maintain the nutrition of their own skin covering, and a newly transplanted surface over such a wound may not survive. This is seen in radiation burns and in chronic leg ulcers. The same conditions are also seen in gunshot and shell fragment wounds where extensively torn tissues have healed (or attempted to heal) in contracted, dense scar masses, the surfaces of which repeatedly ulcerate. Such wounds may have rough, keratotic surfaces. This may be especially true in 'through-and-through'



FIG. 1G.—Roentgenogram of hand shown in Figure 1, Color Illustration.

injuries, because the track of scar tissue completely penetrates the area, so that, in a dissection, the surgeon does not encounter a soft, normal bed of tissue.

"The factors to be balanced in planning satisfactory wound closures in preparation for some subsequent bone, nerve, or tendon repair are, briefly: (1) the preparation of deep tissues to carry adequate minute blood supply to maintain the surface repairs, by the resection of surface and deep scar continued into an area that will furnish satisfactory circulation; and (2) the designing of a surface closure through the use of local flaps, skin grafts, or direct or delayed pedicle flaps."<sup>1</sup>

These direct flaps also may be used within the first few days of the original injury, and tendon and bone fragments can be saved and bone union advanced. This is a marked advantage over the plan of letting wounds collapse and heal, with distortion, so that scar has to be resected and tissues

replaced in position when the repair is undertaken weeks later. This has been recorded,<sup>2</sup> and Colonel E. M. Bricker has reported, by personal communication, that many early flaps have been used successfully in the Plastic Surgery Centers in the European Theater.

*Diagnosis and recording* of arm and hand injuries is extremely important, and a separate note for each finger is required. Sensation in fingers is

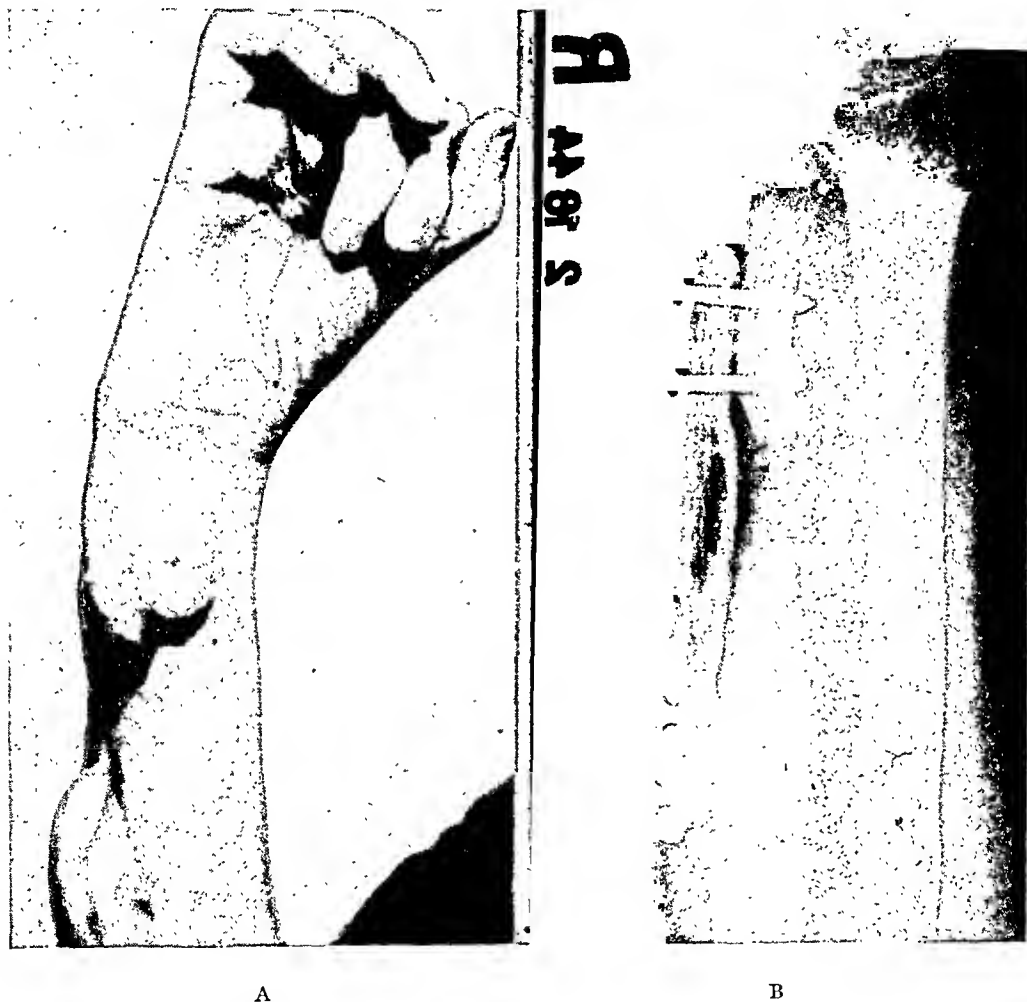


FIG. 2.—A to F—Shell fragment wound of arm with loss of bone graft from breaking down of the scar. Extensive replacement of soft tissues with direct flap and successful secondary bone graft. A soft-tissue shadow of the flap may be seen also on the roentgenogram.

of paramount importance, and the response to pin-prick is always obtained and recorded. On this point of sensation may depend the decision of trying to save or to remove fingers. This is an evident finding, but one that apparently should have attention called to it frequently. This is often tedious in a flood of patients, many with both hands damaged, but it is *always* done and recorded and the notes referred to in the operating room, because the response cannot be obtained with the patient under an anesthetic.

*Simplified Designation of Fingers and Joints.*—To avoid repeated use of cumbersome terms such as “the metacarpophalangeal joint of the middle finger” or the “distal interphalangeal joint of the index finger,” a simple (if drab) method of recording can be used, with relief and speed, namely, the

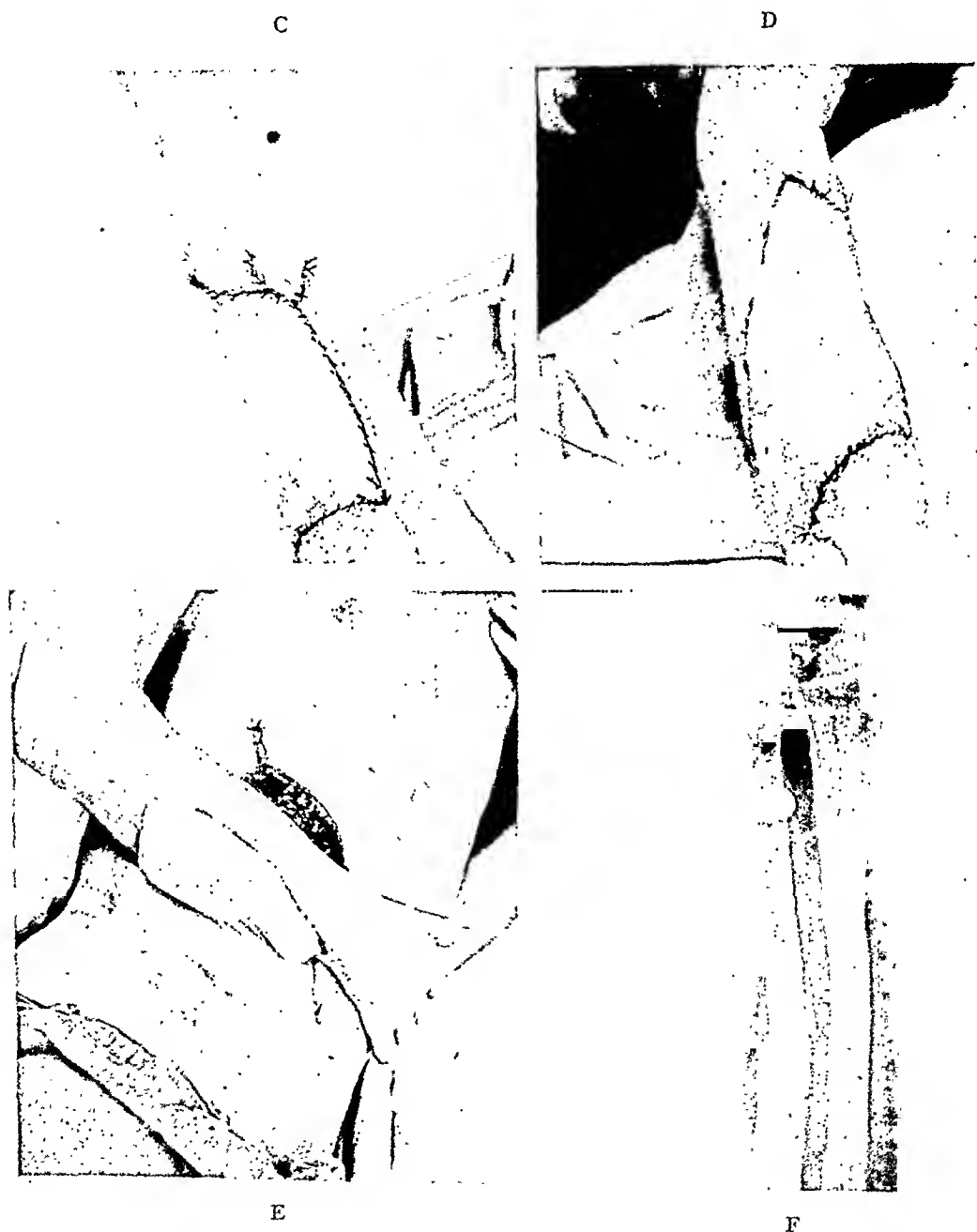


FIG. 2 (Continued)

fingers are simply called 1, 2, 3, 4, and 5 and the joints A, B, and C. Thus, the above long designations become simply “3A” and “2C.” If desirable the metacarpals and phalanges are called W, X, Y, Z and “the metacarpal of the ring finger” becomes “4W” and “the middle phalanx of the little finger” becomes 5Y. A simple chart can be used, but seldom has to be



D

C

B

A

FIG. 3

FIG. 3.—A to F—Extensive loss of soft tissue and destruction of bone showing widespread replacement of soft tissue in 18 days with a direct flap from the chest and abdomen, preparatory to deep bone and tendon work.

# DEFECTS OF ARM AND HAND



FIG. 3 (Continued)

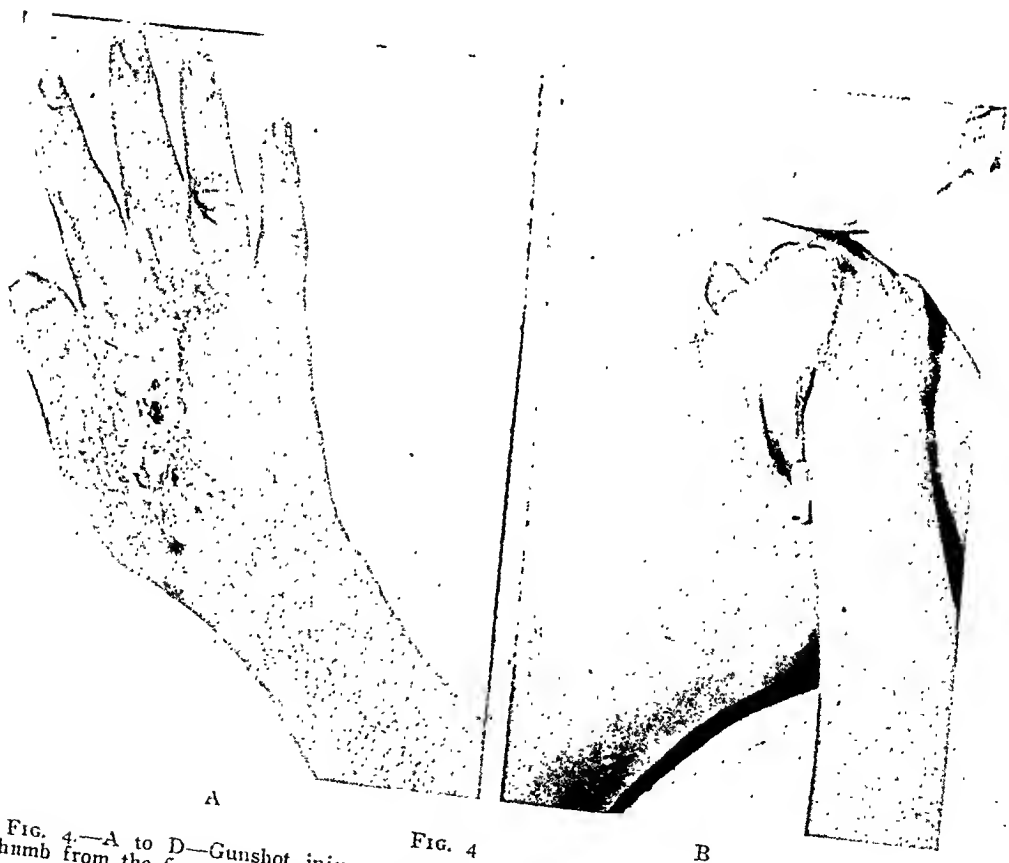


FIG. 4

FIG. 4.—A to D—Gunshot injury of hand with a direct dorsal flap after separation of thumb from the fingers. No deep work required.  
D shows method of internal pin fixation to fix the thumb into position.  
Nomenclature is indicated using 1 2 3 4 and 5 for the fingers. A B C for the joints and W X Y Z for the bones.

referred to. The thumb, of course, has no C-joint or Z-phalanx. This is illustrated in Figure 4.

*Technic:* The open wound is prepared or the scarred area is resected so that adequate minute blood supply is present all around. (For a defect extending around the arm, there is no use doing the entire dissection if the flap cannot reach until it is taken off later.) If the dissection is done under a tourniquet, it is released and hemorrhage is controlled, before the flap is put on (Fig. 1).

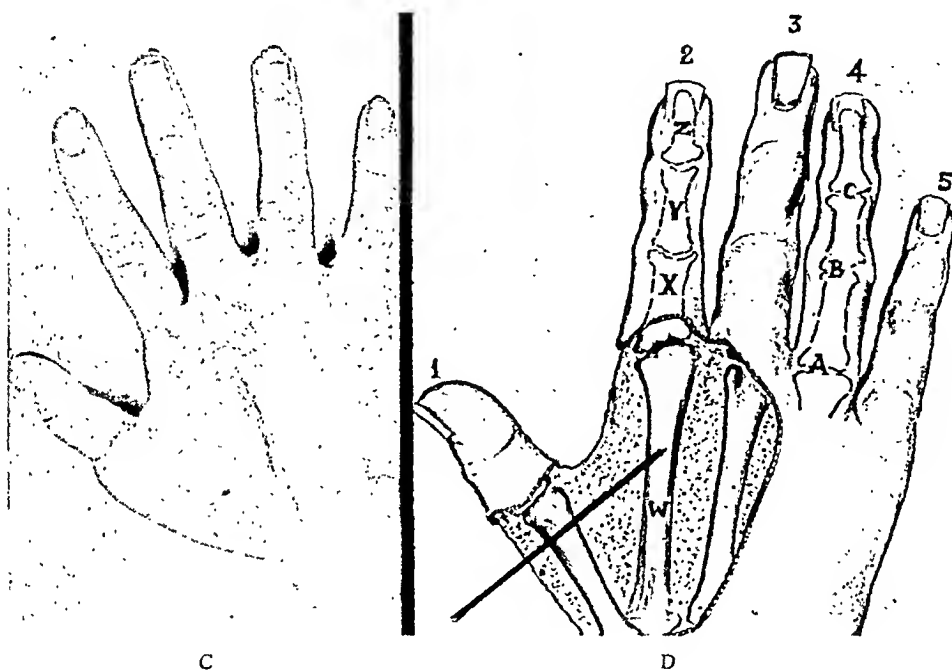


FIG. 4 (Continued)

*The flap is located* in a suitable, comfortable place on the abdomen or chest. For a hand, it is most often in the lower quadrant on the same side, avoiding pubic hair if possible. For the volar surface, the pedicle is usually up towards the chest, and for the dorsal surface, it is usually down, toward the inguinal region. This is, of course, determined by the freedom of movement of the joints, but it is not necessary to put the hand clear across the abdomen. The position of the upper arm and elbow alongside the body and on level with the bed is the most comfortable for hand flaps.

The flap is raised on the principle of a broad, short base, and is designed to fit the defect, but with an over-all additional allowance for shrinkage, which is roughly one-third (Fig. 1). The pattern material is not important, but pliofilm or celluloid are usually available.

The bed of the flap is usually reduced in size with sutures along the edge, and often the remaining defect is grafted with a split-graft. The closed wound makes for easier convalescence and easier care during it—but it is not an essential.

The flap is sewed in loosely along its base with a few interrupted fine

sutures and then is closed around its two or three sides with deep fine sutures and a few skin sutures.

Firm fixation is obtained with a few large strips of adhesive—not plaster of paris—and a cotton waste pressure dressing is put on that can be turned back for easy inspection of the circulation of the flap.

*Pressure dressings* on these flaps are very important, to prevent venous stagnation and the inspection should be done an hour after operation and in the evening, and as often as necessary. Gentle pressure will save more flaps than any other procedure providing, of course, that the position is correct and that there are no kinks (Fig. 1).

Throughout the period of fixation the dressings are kept fresh and clean and adequate dressing service is essential; the success of many flaps has been dependent on nurses in the dressing room, and certainly the comfort of the patient has been possible only through their work.

*Splints* may be necessary to prevent retraction and collapse of hands and they easily can be used while the arm is in place by having neatly cut aluminum splints with or without extensions for elastic traction on the fingers. Traction may be from the fingernails or from skeletal wires. *Internal wires* are often used to fix fingers or metacarpals in position, during the period of attachment if external splinting or fixation will not suffice (Fig. 4).

*Thumb rotation* is always important and is maintained whenever possible. If rotation is not possible, abduction and extension can be relied on.

*Donor areas* are selected, as mentioned, for comfort, to avoid pubic hair, to give the best type of skin. On the hand thin skin of the inguinal region or even of the thigh is preferable for fingers and the palm.

*Free Skin Grafts versus Flaps.*—It is worth noting that on the fingers and on the palm, free skin grafts are preferable to flaps if they can be used; and in some patients, even if there is some question, free grafts will be used rather than bulky flaps. Free full-thickness grafts from the neck are valuable on the dorsum of fingers, to obtain the best pad.<sup>4</sup>

*Cross arm flaps* are used when the good thin skin of the arm is thought to be necessary to secure function in a finger or the thumb web.

*Detaching flaps* can usually be done in 14–20 days. The edge is usually sewed in accurately, but may be left open to be adjusted later. If this plan is followed, the detaching can be done simply under local anesthesia. Partial detaching can be done as indicated, severing part of the pedicle on two to three occasions. Delaying the base of the pedicle by making a regular delayed flat flap out of it is done, if there is a relative small attachment and if there has to be a large wrap-around or further let-in of the flap. This is carried out as a typical delayed flat flap and, of course, makes final detachment delayed.

*The donor site* can often be closed primarily or later, or may be left to heal. Grafting is done if it has not been done at the first operation or if too much more defect has been left when the arm is detached. There have been no gross complaints about the donor sites.

Double pedicles are occasionally used as are also pockets, and tubes.



Tubes, of course, are necessary for thumb reconstruction. But for the general mass of gunshot and shell fragment wounds the direct, nondelayed, nontubed flap is applicable.

*Thinning flaps* is necessary quite often. This fat is not a total detriment because it is this same fat that may make possible any deep work that is necessary. Flabby flaps on the palm, however, may prove to be about worthless for function.

Sensation develops surprisingly well in many flaps and, of course, depends on the presence of nerves in the area; if they are completely blown out, anesthesia will persist.

The following examples of the use of flaps are included as part of the text.

Figure 1 illustrates one of the most distinguishing features of war wounds—that is the lesions produced by shell fragmentation. The irregular, rough, sharp pieces of metal twist and swerve through tissue tearing up nerves, vessels and tendons and shattering bones.

The soft tissue of the palm and the thumb web has become board-like and the thumb fixed, and the roentgenograms show the reason for the loss of softness with the multiple fragments having been driven into the tissues.

Dissection of the scar is done through the whole area, and some of the fragments are shown on the gauze. The skin in this instance has to be taken to get rid of the deep scar.

A direct (or immediate, or nondelayed, or nontubed) flap is raised on the abdomen with the base up and from a thin-skin, hairless area.

The hand is planted in the flap, the arm and hand anchored with adhesive, and a cotton mechanics waste pressure dressing applied.

The hand is taken loose 16 days later and the edge is put down accurately. The abdomen is grafted at this stage, in this instance.

In this flap, fortunately, normal sensation developed and through it a secondary operation for suture of nerve slips to the fingers and for rotation of the thumb was done, with excellent function resulting.

Figure 2 illustrates a badly scarred forearm and the failure of a bone graft put in through dense scar—because the deep repairs can only be successful if the wound heals and does not break down.

Following removal of the bone graft (done elsewhere) the widespread scar was moved down to a good minute blood supply. A direct flap was designed and raised and the arm “planted” in it. Eighteen days later the flap was detached and wrapped further around the arm and sewed in place. The abdomen was grafted. A successful bone graft was put in through the flap and a satisfactory result obtained.

Figure 3 shows massive replacement of soft tissues of forearm in two operations with a direct flap, in 18 days' time. Abdomen grafted when flap was put on and closed when flap was detached.

This patient had asked that his arm be removed. Through this flap the wrist was fused and two tendon transplants were done to give a worth while result far superior to any prosthesis.

Figure 4 illustrates a direct dorsal flap that permits normal enough function so that the two procedures of dissecting the scar and putting the flap in place and detaching the flap 14 days later are all that is necessary.

Internal wiring to maintain separation of the thumb from the fingers during time of attachments to abdomen is shown in diagram.

Method of abbreviated recording, fingers, joints and bones by figures and letters is shown.

Conclusions are outlined in first paragraph.

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## A DESIGN FOR SURGICAL CONVALESCENCE\*

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CONVALESCENCE literally means *growing strong*. It may be defined as the period of recovery from the weakness produced by disease. In surgical convalescence, the disease is to a considerable extent an injury called the operation. Traditionally, it is assumed that convalescence does not really begin until after the effects of injury have ended; in other words, one cannot grow strong unless one has first grown weak. The processes of injury and healing are supposed to follow each other in chronologic order. Yet there is no real reason for believing that injury and repair must be consecutive rather than synchronous. This is of great practical importance, for if healing can begin before the injurious process is at an end, the length of convalescence can be considerably shortened and, perhaps, even made more effective.

Such a synchronous mechanism has been well described by W. G. MacCallum, who compared the process of injury and repair with a burning building. "Long before the fire is extinguished," he wrote, "workmen are found carrying away the charred timbers and enthusiastic carpenters are rebuilding wherever they can." If this opinion is physiologically sound, it is obvious that healing should be encouraged and stimulated as early as possible after the injury; in fact, almost at once. In the present study, therefore, convalescence will be considered as that period beginning immediately following operation.

A second traditional attitude toward convalescence puts great reliance upon the spontaneous efforts of nature. It gives special emphasis to rest. To be sure, active therapy after operation is now carried out, but it is usually confined to procedures combating the effects of trauma itself, such as the injection of saline and glucose, and perhaps blood or plasma transfusions, with the idea of lessening some of the deleterious effects of the injury. However, once these effects have come to an end, the process of healing is left strictly to nature. Even the patient's nutritional needs are left to the vagaries of his appetite.

Actually, there is no more reason why surgeons should rely upon the spontaneous efforts of nature during convalescence than at any other time

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unless such a passive policy really produces the best results. Medical history is replete with examples of scientific advances which developed because of impatience or disappointment with nature. While it is true that mortality from operations has steadily fallen, complications have gradually lessened, and the frontiers of surgery slowly extended, scientific advance should never be looked upon as having achieved its ultimate goal. Satisfaction often paralyzes, whereas dissatisfaction stimulates. Thus, a critical study of the spontaneous healing process called surgical convalescence is not only justified, but is most urgently needed to increase postoperative therapeutic possibilities.

Interest in surgical convalescence has been greatly stimulated by the present war, probably because the problems presented by large numbers of injured soldiers and sailors and marines accelerate clinical investigation. More important, however, is the fact that many of the injuries suffered in battle involve a long period of treatment, including the necessity for repeated surgical procedures. During this long hospital stay, many disabilities are observed which aggravate the problem of healing and prolong the convalescent period.

The term rehabilitation has been used to describe the later phases of convalescence. It implies special procedures for combating many of the deleterious effects of prolonged convalescence. From the physiologic point of view, rehabilitation and convalescence are intimately connected—the more efficient convalescence, the less need for rehabilitation. As a result, considerable study has been given to the process of healing immediately after disease and injury.

Much of this work has been initiated by the Army Air Forces, and a planned detailed convalescent program has been instituted with the aim of improving on the *laissez-faire* procedures of the past. Howard Rusk has reported that this plan of physical and educational training has reduced the length of hospitalization, served to maintain old or develop new skills, restored morale, and increased military knowledge.

Any information throwing light upon surgical convalescence may prove of considerable value not only in the care of soldiers injured in war, but also of those injured in civilian life, and even those injured by choice in a planned surgical procedure.

There is great danger that the lessons learned in wartime will be lost in peace. For example, a thorough convalescence program was worked out and used during World War I by John Bryant, who, with prophetic foresight, realized his work would "have been forgotten, to be rediscovered rather late in the next war." This was written in 1927. However, there is at present so much interest on the part of civilian surgeons in problems of convalescence that study will probably be continued after the war is over.

An important manifestation of this interest was the formation by Dr. L. H. Weed of the National Research Council in 1943 of a Committee on Convalescence and Rehabilitation. As a member of this Committee representing general surgery, the senior author was privileged to participate in

its meetings and activities. From the comembers and especially the chairman, Dr. Wm. S. Tillett, came much of the stimulus responsible for carrying out the present study. Many ideas expressed herein emerged from the group's deliberations, for which grateful acknowledgment is made.

#### FACTORS IN SURGICAL CONVALESCENCE

There are, of course, a great many factors which influence the healing process, including all the advances made in surgery during the past century. It is evident that excellent anesthesia and meticulous surgical technic, a careful aseptic ritual, chemotherapy, transfusions, *etc.*, are essentials without which the highest degree of healing cannot be achieved. These factors deal more directly with the operative procedure itself. They will not be discussed here, because their importance is realized and they have been given adequate attention elsewhere. In this study three nonsurgical factors will be described. These form a tripod upon which the present design for convalescence is based. They may briefly be described as follows:

A. *Psychogenic Factors*.—These deal with the personality of the patient and his reaction to the surgical procedure, both before and after the operation. They may exert either a favorable or a deleterious influence upon convalescence, depending to a considerable extent upon the surgeon in charge. Most of the deleterious influences are due to ignorance, fear and apprehension, based somewhat upon an accumulated background of misinformation sometimes transmitted by word of mouth or by misinterpretation of chance remarks overheard after entry into the hospital. Much of the influence of psychogenic factors has to do with the morale of the patient and with boredom, particularly when the surgical disease requires long periods of hospitalization and repeated surgical procedures.

B. *Physical Factors*.—These comprise changes due largely to the influence of bed rest and immobilization. The most important of these changes are those which lead to pulmonary and circulatory accidents. Less obvious and dramatic, though of considerable importance, are disturbances in neuromuscular abilities and the various changes described as the atrophy of disuse. The general term "deconditioning" is now often applied to the effects of immobility. Other physical factors associated with bed rest are more subjective and deal with the difficulty of performing such normal functions as defecation and urination in the horizontal position. Because all of these deleterious effects arise from immobility, it is obvious that they can be combated simply by encouraging movements from the very beginning of injury while the patient is still in bed, and by early termination of bed rest, technically called early ambulation.

C. *Nutritional Factors*.—These deal with the influence of operation on the nutrition of the patient; in other words, with the phenomenon of malnutrition, which practically always is seen after surgical procedures. Malnutrition is basically a wastage of body tissues, of which the most important is protein, and to a lesser extent loss of vitamins. In large part, this malnutri-

tion is due to starvation, i.e., an inadequate dietary intake, based on anorexia, which is largely preventable. It also is due to the fact that surgical procedures lead to excessive losses, particularly of protein, much of which may be difficult to prevent or correct until after the effects of injury are over.

The three above-mentioned factors, while quite distinct, actually are intimately connected. For example, early termination of bed rest, when properly carried out, greatly improves the morale of the patient, eliminates many of his unfounded fears, and increases his appetite for food so that anorexia is automatically lessened. On the other hand, a good dietary intake increases physical strength and thus encourages an early return to full movement, which in turn improves appetite and morale and increases the capacity for physical activity. In this sense, there is a reciprocal influence of these factors one on the other. By taking advantage of all of them together, the beneficial effects obviously are increased.

#### PREVIOUS WORK

Convalescence, as such, has been the subject of surprisingly few publications. Up to 1938, one can find less than 150 titles in the entire bibliography published by the Surgeon General's Library under this general heading. Moreover, practically all of this literature is concerned with the period of convalescence following discharge from the hospital, with special reference to the establishment of so-called convalescent homes. As applied to a surgical patient, this has been called<sup>1</sup> the period "after the stitches were out and his hospital record neatly filed away."

A complete review of the literature on convalescence was published in 1927 in a monograph by Bryant, who also described his own experiences with a convalescence program he instituted in the medical corps of the United States Army during World War I. Included also was a chapter devoted to pre-operative and postoperative care, titled the "Medical Aspects of Surgical Convalescence."

The most recent extensive publication on convalescent care followed a conference held in 1939 under the auspices of the New York Academy of Medicine.<sup>7</sup> All specialties were covered, including surgery, but the period discussed was that following discharge from the hospital, and dealt almost entirely with the advantages of special convalescent homes or hospitals. By contrast, the present study is devoted to the convalescent period preceding discharge and beginning immediately after the operation.

Consideration of the three factors already mentioned leads to further observations which have a bearing on the subject of convalescence. These will now be reviewed.

*Psychogenic Factors.*—The influence of psychogenic factors in surgery has received very limited study. Surgical diseases have such a large physical component that many surgeons would probably deny the influence of psychic factors entirely. Yet it is obvious that every individual reacts to psychic as well as to physical trauma in various ways, many of them deleterious.

and that these reactions are part of his clinical behavior even if he has a carcinoma of the stomach or a fracture of the femur. To overlook the influence of mind over body is to neglect an important part of the clinical picture and to miss significant therapeutic possibilities.

The work of George Crile on the deleterious effects of unpleasant and painful stimuli before and during operation falls into the category of psychogenic factors even though his studies dealt largely with physiologic effects, particularly on the circulation. Pharmacologic means to minimize preoperative apprehension are important and widely used. Excellent anesthesia in general and gentle operative technic also tend to minimize deleterious psychic trauma. While definite noxious stimuli, such as severe pain, are responsible for many of the psychic insults during and after operation, others are based on unfounded fears. Ralph Waldo Emerson realized this when he said—

"Some of your hurts you have cured  
And the sharpest you still have survived,  
But what torments of grief you endured  
From evils which never arrived!"

A stimulating and direct approach to the study of psychogenic factors in surgical patients has been made by Barney Brooks. He brought a psychiatrist and a psychologist into the surgical wards for the study of patients, both before and after operation, by modern psychologic methods. The results, while only described in part, not only advanced knowledge of surgery, but also of psychiatry. It was interesting to note that only two patients on the ward failed to submit willingly and agreeably to such psychiatric investigation. On the other hand, private patients objected almost universally to such study. This difference was explained by the fact that the psychiatrists were not labeled as such on the surgical wards, but were permitted and even encouraged to pose as members of the surgical staff. Interestingly, pre-operative apprehension was not common; many patients on the contrary really awaited operation as something to be achieved. Significant of the objective clinical value of the study were 14 consecutive cases of acute appendicitis, all showing acute inflammatory disease at operation; seven of these patients were found to have definite evidence of anxiety of sufficient gravity to be of clinical significance. In two other cases operated upon during the same period in which no organic change was found in the appendix, psychiatric examination disclosed sufficient evidence indicating that the clinical manifestations of acute appendicitis were really those of a neurosis.

In another clinic, a psychologic screening test was carried out in a large series of hospital patients by Wolff. The incidence of personality problems in general surgical as well as medical wards was found surprisingly high. At least 35 per cent of these patients exhibited changes of clinical significance, yet the attending physician and surgeon were unaware of the fact in any of them. In an extensive discussion prepared by the Committee on Convalescence and Rehabilitation of the National Research Council, many of these

psychogenic factors are described as they apply to all sorts of illnesses, including surgical cases.<sup>31</sup>

It is true, of course, that from time immemorial a surgeon with common sense and a real feeling for his patient automatically recognized the importance of psychogenic factors. Yet there has, in general, been an almost complete silence on the part of textbooks and teaching curricula regarding their influence. If such factors are of importance, they should be discussed and studied openly. If they are valuable during the surgical convalescence, they must be incorporated into any design for convalescence which has as its objective an improvement upon past efforts.

*Physical Factors.*—The virtue of rest as a therapeutic procedure is so deeply ingrained in the tradition of the healing art and has been so emphasized and extolled by the great leaders in medical thought for so long that it was almost considered heresy to describe and emphasize any deleterious effects which could be directly attributed to this general procedure. Yet as long ago as 1886 Lucas Champonniere<sup>22</sup> denounced eloquently the evil effects of prolonged immobilization in the treatment of fractures. He expressed for the first time the belief that repair is more rapid and complete when some movement is permitted. He claimed that even pain is less with early movement because immobilization merely postponed pain which actually is worse the longer immobilization precedes the start of movement. He, therefore, advocated early mobilization and massage. It is noteworthy that he expressed the same idea 25 years later<sup>23</sup> with greater emphasis, based upon his added clinical experience.

Early mobilization of the entire body by shortening the period of bed rest after surgical operations was first carried out in 1899 by Emil Ries, a gynecologist practicing in Chicago. He described the beneficial effects of early ambulation in a series of patients who were allowed up on the first or second postoperative day following hysterectomy. This lead was not followed even by other gynecologists, for Howard A. Kelly, in 1911, wrote as follows: "The timid surgeon does not want to drag a miserable, depressed, suffering patient out on the floor so soon after an aggressive operation."

Yet the dangers of recumbency have long been realized by surgeons as far as older patients are concerned. Few surgeons would hesitate to get a patient out of bed almost immediately after operation if the patient were in his 80's or 90's. The advantages of such early termination of bed rest are freely acknowledged. The deleterious effect of prolonged bed rest in the aged has been realized even in other types of disease, the evidence being summarized very well by LaPlace and Nicholson in 1938. Although early ambulation produced no deleterious results in the aged, it was not widely used in younger patients. Most textbooks recommend, as a routine, bed rest for at least ten days following abdominal operations.<sup>9</sup>

A complete collective review of observations on early termination of bed rest after operation was published in 1943 by Newberger.<sup>28</sup> In this review only 44 of the 189 references to the literature were in the English language and



nearly all were published previous to 1914. With few exceptions, and those from European centers, the communications were all from nonuniversity clinics. By 1922, two English surgeons, Claremont and Rowland, stated the case for early termination of bed rest convincingly. As a result of Newberger's review, one definitely gets the impression that early ambulation has many advantages, without real disadvantages, and one wonders why the idea failed to gain general acceptance. Perhaps it was due to a lack of confidence in the security of catgut sutures with which most wounds were closed. Experimental observations have been very meager indeed, but Newberger himself<sup>29</sup> carried out a study on the tensile strength of healing wounds in rats, and was able to show that immobilized animals exhibited a definite difference as compared with those who are exercised. While the tensile strength in the two groups was the same on the third and on the tenth days, the exercised animals showed a definitely greater tensile strength at the fifth day.

"The Abuse of Rest in the Treatment of Disease" formed the subject of a symposium held in 1944 at a meeting of the American Medical Association. Medical, surgical and other types of disease were discussed.<sup>36</sup> A paper by Powers presented detailed data in regard to the effect of early ambulation after a variety of abdominal operations as compared with control cases treated by traditional methods. The evidence was clearly in favor of early ambulation.

Two other communications on the early termination of postoperative bed rest have appeared in the past few years. Leithauser, in 1943, as a result of his experience, was very much in favor of early ambulation. He included observations on the vital capacity of 21 of his cases, 13 appendicectomies and eight cholecystectomies. The return to a normal vital capacity was much more rapid as compared with measurements reported by others in patients treated by the usual period of bed rest. Nelson, on the basis of over 400 personally observed cases, was also greatly impressed with the value of early postoperative ambulation. Only three cases exhibited partial wound disruption and only two developed small incisional hernias. In the present war a number of studies have been made on the beneficial effect of early ambulation following abdominal operations, and especially in head injuries in military personnel. A witty and provocative editorial in a recent number of the *Lancet*<sup>12</sup> entitled "Keep Moving Please" summarized much of the current English reaction to early ambulation after operation.

Among the evil sequelae of complete bed rest, interestingly discussed by Dock, are circulatory changes associated with thromboses and emboli. There is, of course, a large literature on the etiology of postoperative thrombosis and embolism. The influence of bed rest and immobility is convincingly shown in a recent study by Hunter, Krygier, Kennedy and Sneed. They dissected the leg veins in 169 cases at autopsy for the presence or absence of thrombosis. All cases had been in the hospital for 48 hours or more before death. They were divided into two groups: (1) Those who exercised in bed and were ambulatory up to 48 hours before death; and (2) those who

did not exercise and were nonambulatory. In the first, or ambulatory group, only five medical and two surgical cases showed thrombosis, an incidence of 17.9 per cent; in the second, or nonambulatory group, 42 medical and 27 surgical cases showed thrombosis, an incidence of 53.1 per cent. In a discussion of the literature on the etiology of thrombosis, these authors emphasize confinement in bed as the common denominator of all studies.

Other effects of bed rest could be discussed. Fairly well known are all the changes associated with the atrophy of disuse. These occur to a lesser or greater degree depending on the degree and duration of immobility. Then there are metabolic changes, alterations in cardiovascular mechanisms, loss of neuromuscular skill, *etc.* Many of these changes have been discussed in a "Symposium on Physiological Aspects of Convalescence and Rehabilitation" published by the American Physiological Society.<sup>37</sup>

It is obvious from this brief résumé of the literature that bed rest and immobilization cannot be viewed with complacency. Their effects must be looked upon objectively, and their disadvantages weighed impartially against their advantages with accurate attention to detail in terms of the actual results achieved. Bed rest and immobilization have well known and definite beneficial effects which must be utilized without, if possible, producing any deleterious results. To do so completely, probably is impossible.

The elusive quality of judgment must be used in order to decide just where to draw the line in regard to the termination of bed rest. Certainly, it should be utilized only insofar as it achieves beneficial results and no longer. When its advantages begin to diminish, it should be terminated at the point where the advantages of mobilization more than outweigh the disadvantages of immobilization.

From the studies reported, it would seem that early ambulation has the following advantages: a lowered incidence of postoperative, particularly pulmonary and vascular, complications; less nausea, vomiting and abdominal distention; an earlier return of normal functions of the bladder and the bowel; a beneficial psychologic effect on the patient's morale and mental status; and the acceleration of convalescence permitting an earlier return to working ability with resultant economic savings to the patient.

*Nutritional Factors.*—In view of the wide interest in nutrition, it is surprising to note the dearth of study of the general nutritional changes after surgical operations. Yet it is a commonplace observation that practically every surgical patient suffers some loss of body weight. This has been considered inevitable and, for this reason, was perhaps overlooked. A brief discussion of the nutritional factors in convalescence was written by the Committee on Convalescence and Rehabilitation of the National Research Council.<sup>26</sup>

Wastage of body tissue in itself may be of little physiologic significance unless protein tissue is affected. Weech has shown that plasma proteins begin to fall with the very onset of a protein-free diet. That protein frequently is lost in surgical patients is shown by the high incidence of postoperative hypoproteinemia, a defect which often has serious clinical implications. Attention

was first called to this deficiency, particularly as a cause of postoperative edema, in 1933, by Jones and Eaton. Since then, postoperative protein deficiencies have been emphasized by many observers.<sup>13</sup>

Of the causes of malnutrition in surgical patients, the most obvious is an inadequate dietary intake. This is due to one or more of several factors.<sup>14</sup> If the patient is able to eat, starvation occurs either because a restricted diet is imposed upon him, or because of anorexia which may follow surgical procedures. If the patient is unable to take anything by mouth, starvation is due to the fact that, although the parenteral route is used, the fluid given contains inadequate calories, vitamins and usually no protein.

A second mechanism often responsible for malnutrition is the excessive loss, particularly of protein, which occurs as a result of the operative procedure. This excessive loss occurs in two ways. The first is actual spilling of blood itself or extravasation of blood, plasma or exudate into the traumatized area, thus, resulting in hypoproteinemia, or anemia, or both. The second is a breakdown of protein tissue, occurring after operation and in many infections, which has been described as "the toxic destruction of protein." The magnitude of these losses may be tremendous; whereas the normal requirement for protein balance usually is placed at about 70 Gm. per day, the amount lost after operation may reach a figure which is two to four times as great. In other words, to prevent any protein starvation, a postoperative patient might have to assimilate the equivalent of 200 to 300 Gm. of protein each day. This actually has been done by increasing the intake of protein to this level.<sup>8</sup> Increased physical strength, weight gain and more rapid convalescence were observed. On the other hand, other observations have indicated that, in well nourished patients, protein losses for a certain period after operation cannot be corrected because nitrogenous food given during this catabolic phase cannot be assimilated.<sup>3</sup>

Clinical manifestations attributable to protein starvation after operation have been summarized in a previous communication.<sup>14</sup> They include hypoproteinemia, postoperative weakness, asthenia and anorexia, nutritional edema, lowered resistance to infection, impaired liver function and, in extreme cases, a fatal outcome. There is a growing realization that starvation cannot be disregarded because many postoperative complications are directly attributable to it. Starvation is no longer necessary even if the patient can take nothing by mouth; methods are now available for almost complete parenteral alimentation.<sup>16</sup> Besides protein, postoperative deficiencies in vitamin C have been observed in normally nourished patients as part of the operative trauma.<sup>24</sup> Whether thiamine or other vitamins are lost or destroyed after surgical procedures is not known.

#### THE PRESENT DESIGN FOR CONVALESCENCE

The design for convalescence used in the present study was based on the psychogenic, physical and nutritional factors already discussed. The influences of these three factors were studied in each of 79 consecutive surgical

cases. All patients admitted to one surgical female ward were observed for a period of four months, from April to September, 1944, and all male patients admitted to another ward for a succeeding four months, from September, 1944, to January, 1945. As controls, the same wards were used on the alternate periods, the patients receiving during this time the customary postoperative regimen. This admittedly is not an ideal method of clinical study, for it would have been preferable to study concurrent controls selected alternately as they were admitted to the ward.

Unexpectedly, we soon observed that the establishment of this design on all patients of a particular ward in itself had an interesting result—rivalry between patients in their desire to achieve complete recovery. They encouraged each other to carry out the program of early movement and to increase their dietary intake—about which they were all told ahead of time. It was clear that the morale of the ward was definitely improved and that, inadvertently, we were achieving what is often called group psychotherapy.

The details of the program were carried out as follows: Each patient on admission had an interview with the visiting or the resident surgeon who discussed completely the plans for diagnosis and for treatment. The objective to be reached was described and emphasized. Each patient was told that we expected and would encourage him to walk within a few days after operation, but that he would not be urged to do so unless he wished. Fear was usually the greatest deterring factor. Patients were told that their wounds would be so securely sutured that there was no danger of disruption, and they need fear no accidents by following the program. Once they heard of other patients walking within a few days after operation or actually saw this themselves, their fear nearly always disappeared. For example, one of our patients, a 66-year-old male, following gastric resection, elected to start walking on his third day. When his friend in the next bed saw this, he decided to do even better after his gastrectomy. He got up and walked on his second postoperative day, in spite of his 72 years of age and an ankylosed hip. Each patient was told that feeding would be given intravenously while nauseated, but that he would be expected to eat within a few days after operation, at first liquids, but soon solid food. They were told that walking would be encouraged in increasing lengths each day, and that we fully expected them to leave the hospital feeling as strong or even stronger than they did when they entered. They were then questioned as to the existence of any fears. They were encouraged to tell of any disturbing experiences that friends of theirs had had following operation, and the facts were explained. Their own plans after leaving the hospital were discussed when possible or necessary. In discussing these matters, each patient was considered individually. A rigid routine was avoided as much as possible; only the general outlines of the design were followed. In patients depleted by their disease, preoperative preparations included procedures such as correction of nutritional deficiencies by various methods not germane to the present discussion.

Immediately after the more serious operations, an attempt was made to

achieve complete replacement therapy. A sufficient transfusion of whole blood and/or plasma was given to correct any losses resulting from the operation itself. The amount varied from 500 to 2,000 cc. of whole blood and from 500 cc. of plasma to 1,000 cc. Postoperative hematocrits and plasma protein determinations helped to decide whether deficits still existed even after such replacement therapy. A general anesthetic was employed in nearly all cases. Nonabsorbable sutures of silk and stainless steel were used.

As soon as the patient was conscious and rational after awakening from the anesthetic, he was reminded that he was to move about in bed at regular intervals. Pain, of course, was the usual deterrent, but sedatives were used only when necessary. Physical methods and suggestion, such as the achievement of a comfortable position and reassurance, were preferred. There usually is a good deal of pain in the wound for 24 hours, but much of it may be avoided if the skin sutures have been placed loosely. Early movement of the patient was generally confined to regular exercising of the legs and of the arms and periodic overventilation by deep breathing. The patient was encouraged to turn frequently. Almost immediately he was allowed to sit up in bed at intervals. Each day the question of walking was discussed with the patient. In any case, he was permitted to sit on the edge of the bed with his feet dangling the day after operation. In most cases, patients could be encouraged to stand on their feet by the second or third day. In only a few cases did this occur after the fifth day. In Table I these figures are listed, together with the various operations carried out.

Nutritional requirements were met at least in part from the very first. If the patient could eat he was encouraged to do so at once. In most cases vomiting will follow attempts to drink even water, particularly following a general anesthesia; in other cases the oral channel cannot be used because the surgeon wishes to keep the gastro-intestinal tract at rest. In either case the parenteral route must be used.

The usual routine after the more severe operations was the intravenous injection of two liters containing 100 Gm. each of glucose and hydrolyzed protein (amino-acids)\* and about 5 Gm. of sodium chloride at a  $pH$  of 6.5. One liter was usually given in the morning, and one in the afternoon. Often an additional liter was given of 5 per cent glucose in water (or saline if indicated). One gram of vitamin C was injected into the muscle each day. Two other daily injections were given containing thiamine, riboflavin and niacin. This regimen was used for as short a period as possible, *i.e.*, until sufficient food was taken by mouth. Patients were encouraged to take fluids by mouth as soon as the surgeon considered it safe. This often occurred within a day or two in simple cases, or as soon as the effects of the anesthesia had worn off. In the case of gastric resections the period was longer, often three or four days, before liquid was permitted. At first simple fluids such as tea, broth and fruit juices are given, but if tolerated without vomiting or distress, milk is added. A high protein drink consisting of skimmed milk

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\* Amigen.

powder added to milk, 100 Gm. to the glass, is often a useful way of increasing the protein intake.

The importance of giving priority to protein is suggested by experimental studies<sup>15</sup> showing that in the absence of malnutrition much of the caloric requirement may safely be met by the patient's own tissue fat. But even liquids are supplemented within a day or two by eggs and other solid foods which are added as soon as possible. In all cases except gastric resection a full, well balanced diet was taken by the end of the first week following operation. Considerable individual variation was observed. This often required special attention to idiosyncrasies of the patient's appetite when it did not interfere with the ingestion of good food.

No specific attempt was made to increase the morale of the patients or to combat boredom in any special way. Most civilian patients are in the hospital for such a short period that factors of morale probably are not as important as they are for military personnel, especially when prolonged hospitalization is necessary. Nevertheless, we are convinced that an active program of education, diversion and entertainment has its place even in an ordinary surgical ward and particularly when the patient is in a single room and when hospitalization is prolonged. Such measures, including occupational therapy, will beneficially influence surgical convalescence.

In a number of patients, significant chemical data were obtained. The 24-hour urinary output was collected and its nitrogen content determined. Specimens of heparinized blood were collected and cell volume, plasma albumin and globulin determinations carried out. These patients were weighed before operation and on discharge. Chemical methods for fractional plasma proteins were those described by Campbell and Hanna. The Kjeldahl procedure was that of Sobel, Yuska and Cohen.

#### PRESENT FINDINGS

The results of this study may be listed under the headings of (a) bedside or clinical observations; and (b) chemical and physical or laboratory measurements.

Clinically, the bedside findings may be described, first, in terms of beneficial effects and, second, in the absence of deleterious ones. In regard to the first, the beneficial clinical observations were quite evident in the general condition of these patients. They felt better and exhibited much less of the postoperative asthenia and depression which may follow a serious abdominal procedure. This was evident both to the attending physician and the nurses in attendance on the ward. There was an obvious decrease in the amount of nursing and attendant care, particularly in the serving of trays and the routine making up of beds, especially in the female ward, because the patients were able to take care of themselves early in their postoperative course.

The most striking observation, however, was the clinical condition of the patient at the time of discharge, which, in this series, was not reduced in length from the usual fortnight. Invariably, they felt quite strong and vig-

orous. Many of them voluntarily expressed their ability to do a good day's work. Indeed, many patients after early ambulation stated that they were strong enough to leave the hospital and to go home even before the stitches were removed. They often objected to our requirement that they remain the usual fortnight. This was in striking contrast to the asthenic condition of the control patients who were often permitted to go home the next day after they got out of bed. This clinical result was well expressed by two private patients treated by the present design. The one, after a cholecystectomy, stated that she had made plans to spend six weeks with her mother recuperating. On discharge she felt no need at all for such recuperation, yet she had not made plans to return to work. She was very much pleased when it was suggested that she enjoy an active vacation. The other, after a partial gastrectomy, left the hospital on his 12th postoperative day and called the next day requesting permission to return to his desk job.

On the negative side, regarding the diminution of deleterious effects, there was no clinical evidence of embolism in any of the 79 cases. During this same eight-month period, among the control cases treated on the same wards, three vascular accidents were observed among patients who were not treated by the present design and who were kept in bed for the usual ten-day period. In two of these patients, the accident proved fatal. One of them was a patient who had had a saphenous ligation. Because the wound became infected, she was kept in bed for seven days. Death occurred suddenly as soon as she was allowed to stand. The second case was an uneventful cholecystectomy who was kept in bed for ten days and in whom sudden death followed immediately her getting out of bed. The third was an ileostomy for ulcerative colitis, who on the 12th day, while still in bed, developed severe evidence of pulmonary thrombosis from which, however, the patient gradually recovered.

In regard to wound disruption, there were none in the entire series of 79 cases. In the control group of patients, two wound disruptions were observed, both requiring an anesthesia and resuture. No observations were made as to the degree of postoperative fever, nausea or vomiting, but the clinical impression was gained that these manifestations were certainly no more pronounced than usual, indeed, probably less so.

The more objective measurements consisted of studies on nitrogen balance and in measurements of the serum proteins and changes in the body weight. Only the data which are more or less complete are presented; these are shown in the accompanying charts. It will be observed that in the control cases there was a loss of weight of about eight pounds and an average fall in the plasma albumin of .20 Gm. per cent between the pre-operative measurement and that on discharge as compared with a loss of but one pound and a gain of .15 Gm. per cent in the plasma albumin in the group treated by the present design. (See Tables II and IIa.)

Comparison of the nitrogen losses in the urine shows a somewhat greater depletion in the patients treated by the traditional routine. This is seen

readily by comparing the losses in the first three days, a period during which no nitrogenous food was taken by mouth in either group. The average loss in the control group receiving no nitrogenous food was 5.8, 8.6 and 9.2 Gm. for these three days, even though the patients had much less serious operations than the group in whom the present design for convalescence was carried out. In this latter group the urinary excretion of nitrogen in the first three days after operation was much greater, yet the negative nitrogen balance was much less, *i.e.*, 4.0, 2.7 and 3.9 Gm. for these three days. This was due to the intake of nitrogen as hydrolyzed protein. (See Tables III and IIIa.)

TABLE I  
SUMMARY OF THE OPERATIONS PERFORMED IN THE 79 CASES STUDIED, AND THE  
POSTOPERATIVE DAY WALKING WAS STARTED

Days after Operation when Complete Bed Rest was Terminated

Operation	1	2	3	4	5	6	7	Total
Inguinal herniotomy.....	12	4	1	4	1	1		23
Appendicectomy.....	2	7	3	2				14
Ventral herniotomy, with fascia trans- plant.....	1	2	1	1	1	1		7
Cholecystectomy.....		2	2	1				5
Gastric resection.....		2	4	1				7
Resection of rectum(abdomino-perineal)		1	1		2	2	1	7
Resection of colon.....	1		1	2				4
Splenectomy.....		3						3
Celiotomy & misc.....	4		4	1				9
Total.....	20	21	17	12	4	4	1	79

TABLE II  
CHANGES IN BODY WEIGHT AND PLASMA ALBUMIN IN PATIENTS  
RECEIVING TRADITIONAL POSTOPERATIVE CARE

Patient	Sex	Age	Operation	Plasma Albumin (Gm. %)		Change in Body Weight (Lbs.)	Days between Operation and Discharge
				Before Operation	Change at Discharge		
1. B. E.	F	26	Inguinal herniotomy.....	4.49	+ .23	— 4	10
2. C. D.	M	59	Appendicectomy.....	4.83	+ .04	— 3	20
3. H. S.	M	55	Appendicectomy.....	4.69	— .42	— 8	11
4. A. S.	M	68	Appendicectomy.....	4.27	+ .19	—10	20
5. M. Y.	F	39	Appendicectomy.....	4.41	— .13	— 9	18
6. A. P.	F	63	Ventral herniotomy.....	4.19	— .13	—12	36
7. M. B.	F	50	Appendicectomy and chole- cystectomy.....	3.86	+ .16	— 3	13
8. S. L.	M	55	Gastric resection.....	4.61	— .32	—10	12
9. L. H.	F	47	Abdomino-perineal resection of rectum.....	4.23	— .10	— 9	26
10. F. R.	F	46	Resection of colon.....	4.04	—1.55	—17	36
11. B. R.	F	31	Cholecystectomy.....	4.56	— .20	— 5	12
12. I. B.	F	65	Cholecystectomy.....	4.19	— .22	— 6	12
Average.....				4.36	— .20	— 8	19

Note that there was an average fall of .20 grams per cent in the plasma albumin level. Note also that there was a loss of weight in each case even following the simple procedure of herniotomy or appendicectomy, the average loss being eight pounds.

These patients were given saline and glucose after operation until they were all able to take simple fluids by mouth. A gradually increasing diet was then permitted. Bed rest lasted for at least eight days following operation.

The above observations are to be compared with a concurrent group of patients (Table IIa) receiving the postoperative care described in this paper.

During this study it seemed apparent to us that patients given parenteral protein and vitamins from the start of the postoperative period began to eat more and sooner and felt stronger than the control cases receiving glucose



and saline alone. In many cases anorexia was apparently based to a considerable extent upon protein starvation itself. This statement may be surprising to many. It may even be questioned by some because it is usually assumed that the patient's appetite can be relied upon to determine when and how much food he receives.

TABLE IIa  
CHANGES IN BODY WEIGHT AND PLASMA ALBUMIN IN PATIENTS  
RECEIVING THE POSTOPERATIVE CARE DESCRIBED HEREIN

Patient	Sex	Age	Operation	Plasma Albumin (Gm. %)		Change in Body Weight (Lbs.)	Days between Operation and Discharge
				Before Operation	Change at Discharge		
1. L. H.	F	41	Cholecystectomy.....	4.40	+ .71	-1	11
2. T. R.	F	50	Cholecystectomy.....	4.43	- .14	+3	12
3. A. W.	F	64	Abdomino perincal resection of rectum.....	4.50	- .37	...	18
4. P. B.	F	42	Abdomino-perineal resection of rectum.....	4.28	+ .35	-2	21
5. E. B.	F	55	Abdomino-perineal resection of rectum.....	3.95	+ .19	-1	26
6. H. C.	F	62	Abdomino-perineal resection of rectum.....	3.79	+ .75	0	47
7. M. W.	F	57	Resection of colon.....	4.01	- .01	-4	17
8. A. W.	F	61	Resection of colon.....	4.27	+ .27	0	14
9. M. C.	F	25	Resection of colon.....	3.64	+ .76	+3	17
10. B. H.	F	27	Ventral herniotomy.....	4.63	+ .08	-3	12
11. J. Z.	M	66	Gastric resection.....	4.38	- .47	-1	18
12. S. S.	M	36	Gastric resection.....	4.26	- .30	-8	15
Average.....				4.31	+ .15	-1	19

Note that there was a slight increase in the average plasma albumin, even though the initial value before operation was similar to the control group listed in Table II. Note also an average loss of only one pound in body weight at the time of discharge, even though the operations in the above cases were much more serious than in the control group.

These patients were all treated according to the design for convalescence described herein.

TABLE III  
TOTAL URINARY NITROGEN EXCRETED BY PATIENTS NOT RECEIVING  
HYDROLYZED PROTEIN (AMINO-ACIDS) BY VEIN AFTER OPERATION

Postoperative Days				1	2	3	4	5	6
Patient	Sex	Age	Operation						
1. H. L.	F	40	Cholecystectomy.....	...	12.5	13.5	9.6	7.9	10.6
2. M. F.	F	46	Ventral herniotomy, with fascial transplant.....	...	8.5	8.4	...	7.5	8.5
3. G. W.	F	39	Ventral herniotomy, with fascial transplant.....	4.3	9.3	9.0	8.5	8.4	7.0
4. J. G.	F	34	Ventral herniotomy, with fascial transplant.....	5.5	5.5	7.4	8.6	12.6	9.0
5. J. B.	F	25	Splenectomy.....	...	3.9	...	12.0	9.7	8.2
6. B. B.	F	17	Splenectomy.....	5.0	10.1	7.9	13.1	9.1	7.1
7. M. H.	F	30	Splenectomy.....	...	12.4	11.1	10.9	9.0	10.7
8. E. W.	F	54	Removal ovarian tumor.....	10.5	...	7.7	9.8	7.5	7.4
9. J. F.	F	55	Radical mastectomy.....	4.0	6.6	9.2	9.7	7.7	...
Average.....				5.8	8.6	9.2	10.2	8.8	8.6

Note the absence of any large excretion of nitrogen, the highest being 13.1 grams. The figures for the first three days represent negative nitrogen balance because intake during this period was confined to injections of glucose and saline solutions and simple liquids by mouth such as tea and fruit juice. Thereafter an increasingly full diet was taken so that the negative balance would be somewhat less. How much less cannot be stated, inasmuch as measurements of the nitrogen intake were not made.

While appetite probably is an adequate guide in a good many young healthy individuals after simple operations, it is apparently not so after more severe procedures, in those already malnourished at the time of opera-

tion, and particularly when fear of eating becomes superimposed upon the natural craving for food. The development of thiamine deficiency, particularly after intravenous injections of glucose, also may play a part in many cases of postoperative anorexia. Even in normal individuals, a voluntary fast will often dull the sensation of appetite after the first or second day. This undoubtedly occurs in surgical patients deprived of protein for a few days after operation. Thus, malnutrition persists and with it comes a

TABLE IIIa

TOTAL URINARY NITROGEN EXCRETED BY PATIENTS RECEIVING  
HYDROLYZED PROTEIN (AMINO-ACIDS) BY VEIN AFTER OPERATION

Postoperative Days				1	2	3	4	5
Patient	Sex	Age	Operation	B	B	B	B	B
1. L. H.	F	41	Cholecystectomy...	5.6 + 6.4	14.3 - 2.3	17.9 - 5.9	9.5	6.2
2. T. R.	F	50	Cholecystectomy....	13.7 - 1.7	10.8 - 4.8			
3. V. S.	F	28	Cholecystectomy....	5.7 + .3	5.6 + .4			
4. M. M.	F	55	Cholecystectomy....	—	—	15.5 - 3.5	10.9 - 4.9	
5. A. W.	F	64	Abdomino-perineal resection of rectum....	—	—	13.1 - 1.1		
6 P. B.	F	42	Abdomino-perineal resection of rectum....	9.3 - 3.3	12.1 - .1	14.1 - 5.1	14.0 - 5.0	
7. E. B.	F	55	Abdomino-perineal resection of rectum....	19.1 - 13.1	14.2 - 2.2	16.4 - 4.4	17.1 - 5.1	9.2 - 3.2
8. H. C.	F	62	Abdomino-perineal resection of rectum....	12.6 - 6.6	14.3 - 2.3	17.3 - 5.3	13.5 - 1.5	13.5 - 1.5
9. M. W.	F	57	Resection of colon....		17.0 - 5.0	22.2 - 4.2	15.6 - 3.6	8.2 + 3.8
10. A. W.	F	61	Resection of colon....		14.1 - 2.1	14.4 - 2.4		
11. M. C.	F	25	Resection of colon....	6.6 - .6		9.2 + 2.8	11.8 + .2	12.7 - .7
12. B. H.	F	27	Ventral herniotomy....	10.8 - 4.8	11.1 + .9	13.5 - 1.5	9.1 + 2.9	
13. W. W.	M	70	Gastric resection.....	7.1 - 1.1	11.6 - 5.6	13.4 - 1.4	15.1 - 3.1	
14. A. A.	M	30	Gastric resection.....			29.6 - 17.6	23.3 - 11.3	18.7 - 6.7
15. J. Z.	M	66	Gastric resection.....		8.8 + 3.2	11.6 + .4	15.5 - 3.5	
16. L. L.	M	42	Gastric resection.....	11.4 - 11.4	21.1 - 9.1	12.9 - .9	13.2 - 1.2	
17. S. S.	M	36	Gastric resection.....	10.3 - 10.3	20.0 - 8.0	23.2 - 11.2	20.0 - 8.0	17.8 - 5.8
18. I. B.	F	28	Closure of fistula....	2.2 - 2.2	8.6 - 2.6	6.9 + 2.1	15.1 - 3.1	17.4 - 5.4
Average nitrogen output.....				9.6	13.2	15.5	14.8	13.9
Average nitrogen balance.....				- 4.0	- 2.7	- 3.9	- 3.7	- 2.7

Note the absence of any large excretion of nitrogen except in Cases 14 and 17, in which severe pulmonary atelectasis developed.

Under column B are listed the daily nitrogen balances obtained by subtracting the nitrogen output from the nitrogen in the intravenously injected hydrolyzed protein (amounting usually to 12 Gm. per day). Note that while positive balance was not often achieved, the degree of negative balance was considerably lower than in the group listed in Table III in cases *not* receiving parenteral protein feeding.

The nitrogen injected in the form of blood and plasma transfusions was not included in the above figures nor in those of Table III.

further impairment of appetite. This may lead to a vicious circle. Many surgical patients undoubtedly reach a state of severe malnutrition in this way, particularly when bed rest and immobilization have formed part of the postoperative regimen, and when the disease itself has increased the requirements for food. These observations would seem to emphasize the advantage of avoiding even short periods of starvation after operation.

#### SUMMARY

A series of 79 patients was studied after a variety of abdominal operations, including some serious ones. Special attention was paid to elimination of deleterious psychogenic factors before operation and during the convalescent period. Movement in bed was begun immediately, and bed rest

was terminated within a few days after operation. Complete starvation was avoided by the inclusion of hydrolyzed protein (amino-acids) in the parenteral injections of glucose and vitamins from the very beginning. Early resumption of a normal oral intake was achieved.

This design for surgical convalescence seemed to produce definite beneficial results when compared with the results in the control group of patients subjected to traditional postoperative regimen. These results were both clinical and chemical. The former included a more or less complete rehabilitation of the patient by the time of discharge from the hospital, thus, eliminating the necessity of further convalescent care. The latter included less loss of weight and an increase rather than a decrease in the concentration of plasma albumin over the control cases. There was a lower negative nitrogen balance in the cases given hydrolyzed protein (amino-acids).

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## PROFITS TO PEACE-TIME PRACTICE FROM SURGICAL EXPERIENCES OF WAR\*

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THE SURGICAL LESSONS of war are learned in a hard school. Their application is immediate and directed to the business in hand. They are learned in the laboratory of day-by-day experience. It is a school which has gathered in its faculty the great teachers and research students of the time; yet it is a school in which every student must be a teacher and every teacher becomes, in turn, a student.

There is no vacation or recess in this surgical school of war, it will remain in session as long as the fighting lasts and until the last wounded soldier has attained "maximum hospital benefit." Yet, as combat draws to a close there will be an increasing number of graduates from this school. From battle-fields and hospitals they will return to the less exacting curriculum of peace. Their diplomas will read simply: "Honorably Discharged," and carry no degree. As alumni of this school, they will carry with them to their offices, and clinics and hospitals a certain fund of dearly-bought knowledge.

Perhaps, in its somewhat limited field of application to civil practice, this knowledge may not be worth what it has cost in time and effort and lives to acquire. What has been gained is but of the greater value because of its price.

It may be well to anticipate this commencement a little, to count the gains that have been made and the progress that has been achieved in surgical practice and investigation under the urgent stimulus of war. What will the graduating Army surgeon carry with him, as a result of his experience, that will help and guide him in the pursuit of peace-time practice?

Certainly, the surgical experiences of war will have their most direct bearing upon the less common injuries of peace. The industrial accident, the automobile crash, the train or plane wreck or the disastrous fire will provide an occasional victim upon whom the war-time arts of surgery may be beneficently practiced. Fortunately these will be relatively few, but there is no doubt that the knowledge required for their better treatment has been not only increased, but much more widely disseminated because of the war.

*Emergency Treatment.*—In dealing with such emergencies, though our facilities in peaceful communities are more stable and readily at hand, we shall not forget the lesson of the need for rapid and safe transportation of the patient to them for the earliest possible skillful care. We know the necessity for aseptic protection of the wound and of strict immobilization of the injured part. We know the life-giving values of fluids administered intravenously, of plasma, of whole blood, either fresh or stored, and of serum albumin and of the need for their quick availability.<sup>1</sup> We have learned, un-

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forgettably, the necessity for the intelligent employment of these materials and know how, by simple laboratory methods, to evaluate quickly and accurately the patient's need of them. Thanks to war-time experience the significance of blood count, specific gravity and hematocrit and the clinical import of their relationship are matters of common knowledge.

The emergency treatment of wounds has come to be much better understood. The value of protection from secondary infection and the deleterious effect of motion in transport of even soft-tissue injuries have come better to be recognized. The advantages of thorough yet tissue-conserving débridement, learned in World War I, and partly forgotten, have received fresh emphasis.<sup>2</sup> The menace of dead tissue and respect for living tissue is a lesson every Army surgeon has learned. There has been gained a new concept of traumatic vasospasm, resulting from vascular, nerve and tissue injury, as a danger to the circulation of the compromised extremity. The values of débridement, sympathectomy and sympathetic block in combating this condition have been firmly established.

The use of plaster casings, after a period of overemphasis, as a means of definitive treatment in open wounds, has assumed its proper place as a measure of protection during transportation. Burns have come to be properly regarded as infectable surgical wounds entitled to full aseptic respect. Largely as a result of war experience the damaging effect of escharotics and the value of pressure dressings and noninterference have been recognized.<sup>2</sup> The advantage of the promotion of early healing, in these and all other large open wounds, by prompt skin-grafting has been well learned. In major injuries of the extremities the Army has taught when, how and where to amputate.<sup>3</sup> The principles it has laid down and consistently followed will unquestionably result in conservation of life and limb and the better fitting of prosthetic appliances in future civilian traumatic practice.<sup>4</sup>

*Bacteriostatic Drugs.*—The need for combating and controlling infection in large numbers of wounded has provided an opportunity for clinical experience with bacteriostatic drugs that could not have been equalled in many years of civil practice. The knowledge thus gained will surely be employed to the future benefit of patients everywhere. Intensive experience with these drugs in military practice has given a new concept of the surgery of infection. The brilliant promise of the sulfonamides has been exceeded by the performance of penicillin.

It has been amply demonstrated that the prompt and continued administration of sulfadiazine upon the receipt of injury is a valuable prophylactic measure against surgical sepsis. Less certain, and open to some question, is the value of the topical application of sulfa drugs to injured or infected tissue; but the weight of evidence indicates the greater efficacy of their systemic administration. Some of the dangers and limitations of sulfa drug therapy have also been recognized, and precautions in their use have been established. Individual drug sensitivity and reactions have come to be better recognized, and urinary lithiasis, damage to renal tissue, and to the hemo-

poietic system are watched for and guarded against.<sup>5</sup> The natural resistance of certain organisms to sulfa medication has been quite firmly established, and the fact of the ability of some bacteria to acquire such resistance has been learned. These factors have modified considerably the use of these drugs.

Penicillin, used for a time almost exclusively by the military, has been put to an extended and searching clinical test. The results will greatly influence future surgical practice. Its brilliant effect in forestalling the activity of invading micro-organisms has taught the possibility of delayed primary closure of débrided grossly contaminated wounds. The converting of destructive compound fractures into clean simple fractures within a few days under its systemic administration is but one example of its efficacy. Its effect on infection already established is hardly less striking. The control it exerts in osteomyelitis and prolonged suppuration, the rapid subsidence of local infections of boils and carbuncles, of the tissue spaces of the hand and foot, of bones and joints, of empyema and lung abscess, and in contaminated operative wounds have taught an entirely new concept of the surgical management of such conditions.<sup>6</sup>

Yet war-time experience with the bacteriostatic drugs, because of its intensity and extent, has not permitted the development of an attitude of over-enthusiastic acceptance of their benefits. The experience has given opportunity for a more complete and just evaluation of their usefulness and shortcomings. It has been shown that their effects on certain organisms, notably of the *Escherichia* and *Clostridia* type, is negligible, and that even organisms susceptible to their effects may become resistant in time. The lesson has been firmly impressed upon the surgeon that the sulfas and penicillin are tools of extraordinary value and usefulness which will greatly supplement but cannot supplant those therapeutic procedures that are based on sound surgical principles. The complete removal of foreign matter and devitalized tissue, protection and the maintenance of strict asepsis are still the keystones of successful wound surgery.<sup>2</sup>

*Fractures and Bone Surgery.*—The management of fractures, simple as well as compound, occurring in great numbers in war-time, has provided an intensive experience for the Army surgeon. This experience has taught him the value and applicability of accepted treatment methods and has furnished an opportunity for their comparison and evaluation. As a result the advantages of judicious use of skeletal traction-suspension methods of the secondary treatment of fractures, especially of the major long bones, have been confirmed. The opportunity to effect early mobilization of nearby joints is distinctly one of these.<sup>2</sup> Immediate metallic internal fixation of contaminated compound fractures has demonstrated its shortcomings. There has been learned, especially in such cases, the danger of loosening of plates and screws, of their inaccurate placement, of the absorption of bone at the fracture site resulting in apparent distraction and nonunion. External fixation splints, which depend for their supporting effect upon pins which penetrate the bone, have been tried and found wanting under battle conditions. Infection and persisting

sinuses about the pin-holes has been their chief disadvantage. Long immobilization in plaster casings, with its attendant stiffening of joints and atrophy of muscles, has been conclusively discarded in simple and compound fractures alike.

The need for prolonged support of the healed fractured femur by an unhinged weight-relieving caliper brace has been shown. The value of the walking encasement in minor fractures of the leg has been well demonstrated, as has the value of the "hanging cast" in certain fractures of the humerus. The extension splint with skeletal traction and functional position splinting in injuries to the bones of the hand has proven its merit.<sup>7</sup> Much, too, has been learned as to the unanticipated frequency of carpal bone fractures, especially of the navicular; of the necessity for their accurate diagnosis and appropriate and successful treatment by immobilization for periods as long as 16 weeks.

With the aid of penicillin much assurance has been gained in the successful prosecution of reparative procedures on bone. Its use in converting potentially infected compound fractures into clean, closed fractures has already been alluded to. Sequestrectomies, it has been learned, if completely done, may be safely followed by early wound closure or skin grafting, even in the presence of long-standing infection. Bone grafts and transplants may be accomplished at an earlier date than formerly with little fear of exacerbation of previously controlled infection. This emancipation from sepsis has largely removed the dread of long-continued or unhealing osteomyelitis.<sup>8</sup>

In compound injuries of the joints the plan of adequate débridement, cleansing, suture of the capsule and open treatment of the remaining wound, accompanied by systemic penicillin or sulfa therapy, has well demonstrated its efficacy in preventing the dreaded complication of joint sepsis.

*Bowel Surgery.*—Surgery of the bowel has made progress as the result of war-time experience, both as regards the early management of injuries and of late reparative procedures. Suture and even resection of injured small bowel has been repeatedly performed with success, to which the bacteriostatic drugs have undoubtedly contributed. Exteriorizing colostomies have become consistently employed life-saving measures where the large intestine has been injured. Again and again there has been demonstrated the value of divided colostomies with complete exclusion of the fecal stream from distal damaged bowel. Complicated fecal fistulae, often with remote openings and associated osteomyelitis have been brought to healing when thus protected, and reparative procedures on rectum, perineum and bladder successfully accomplished. Chemotherapy has played its rôle well here, as also in the later intra-abdominal procedures so frequently needed to restore the integrity of the intestinal canal.<sup>9</sup>

With the assistance of these agents, and with appropriate proximal decompression, surgeons have learned no longer to fear for the result in resection and anastomosis of the large intestine. This attitude will no doubt hasten the acceptance of such procedures, already advocated by a number of surgeons, as applied to the surgery of cancer. Whether the internal use of sulfasuxidine



(succinylsulfathiazole) has contributed materially to the safety of these resections is questioned by some, but its repeated use for the purpose in war-time practice has demonstrated its value to the satisfaction of many surgeons employing it.

*Thoracic Surgery.*—Thoracic surgery, which in the years before the war had made such striking advances, has gained by fresh experience in the military hospitals. Early definitive surgery of chest wounds marks a substantial advance in this field which will surely carry over to civil practice. The early aspiration of hemothorax and the removal of organizing blood by thoracotomy, evacuation and, if necessary, decortication have diminished the incidence of pleural infection and have proven valuable measures for conserving lung function.<sup>10</sup> Still more frequently useful, no doubt, will be the method of early treatment of empyema by repeated aspiration and the instillation of penicillin solution. When coupled with the systemic administration of the drug many operations of thoracotomy for drainage will be avoided. The use of this drug, too, will appreciably reduce the hazards and complications of all pulmonary and intrathoracic surgical maneuvers.

*Vascular Injuries.*—The relative frequency of blood vessel injuries has led to a considerable experience in dealing with vascular occlusion states and with traumatic aneurysms and arteriovenous fistulae. The rôle of sympathetic innervation in influencing peripheral circulation and the values of sympathetic interruption in vasospasm are better understood. The importance of the distinction between progressive dissecting aneurysms with their threat of hemorrhage or pressure and the more stable arteriovenous aneurysms with their respective clinical and therapeutic implications, has been demonstrated and emphasized in experience.<sup>20</sup> The value of maximum safe delay to permit the establishment of collateral circulation has been repeatedly shown.

*Neurosurgery.*—Among the most striking lessons learned from war-time surgical experience have been in the field of neurosurgery. Here, again, the value of these experiences to civil practice will be particularly in the field of trauma. The gain in this is both qualitative and quantitative. By force of necessity the competent neurosurgeons have been obliged to devise and perfect methods of coping with a great variety of nervous system injuries and their sequelae. Moreover, great numbers of surgeons, previously inexperienced in this field, have become familiar with traumatic situations and have been obliged to treat them while learning by precept, example and experience. There can be little doubt that the brain and nerve injuries of civil life will be better treated by better equipped surgeons in consequence.

In the management of compound head injuries the principles of careful investigation, thorough removal of bone fragments and foreign bodies, suction débridement, accurate hemostasis and preservation and repair of the dura have been thoroughly inculcated.<sup>11</sup> So, also, has the principle of early and accurate peripheral nerve repair or, at least, identification. The need for functional, protective support of denervated muscles has come to be well

recognized, whether accomplished by mechanical splinting or by surgical means. In the field of reparative neural surgery advances have been most significant in the evaluation of brain-compromising scars and their removal, in the repair and replacement of injured dura, often with the aid of fibrin film, and in the closure of skull defects with metallic plates. The technics of neurolysis and suture repair of peripheral nerves have undergone great improvement, to which the employment of tantalum wire sutures and fibrin glue have added much. The use of fibrin foam as an hemostatic agent greatly facilitates the work of the neurosurgeon.<sup>12</sup> Much, too, has been learned concerning the employment of nerve grafts, although the results of grafts of major nerves have not been encouraging to date. This fact has led to the development of considerable skill and ingenuity in securing end-to-end union of severed and shortened nerves by neurolysis, transplantation, posture and even bone shortening.<sup>14</sup> In all neurosurgical work the perfecting of the investigative procedures of encephalography and neuromyelography have played a considerable part.

Striking advance has been made in the treatment of those unfortunate patients who have suffered paraplegias resulting from spinal cord injury. General supportive measures have restored their nutrition, cystostomies have been closed and automatic bladders established. Bedsores have been cleaned and healed, often by suture. Directed exercise and training have restored the strength of unparalyzed muscles. Braces have been fitted and patients trained in their use to the extent that many of them have actually become ambulant in spite of what has usually, in the past, proved a completely incapacitating and frequently fatal disability.

*Plastic Surgery.*—Plastic surgery, long the stepchild of various specialties, has come into its own by virtue of the stimulus of war-time needs. While standard fundamental procedures of repair have not been changed, new applications and adaptations have needed to be devised, accepted and taught. The disfigurements and disabilities produced by war's injuries have stimulated and taxed the ingenuity of plastic surgeons to the full. That they have profited by this experience and that many additional competent surgeons have received valuable instruction in this important field cannot be doubted. Three developments, in particular, have added to the effectiveness of this type of surgery. They are the perfecting of methods for the utilization of stored or refrigerated skin grafts<sup>13</sup>; the adaptation of plastic substances, notably acrylic, for the replacement of structural defects about the face; and the use of tantalum wire in place of fascia to replace the action of denervated muscle groups.

*Elective Surgery.*—Experience in time of war with certain nonemergency surgical procedures has given an invaluable opportunity to review their results in large numbers of cases. In this group are the operations for protruding intervertebral disk or herniated nucleus pulposus. Much controversy has developed concerning this procedure, as to its indications, technic and results. From it all has come a generally acceptable point of view, less

enthusiastic than that of some of its more radical proponents, less conservative than that of some of its detractors. This point of view may be expressed as requiring demonstrable neurologic and roentgenologic demonstration of the lesion as indications for operation. Army experience has led to the conclusion that in such cases surgical relief of the condition may be expected to result in improvement in about 60 per cent of the cases, but only after the passage of time and with protection of the patient from lifting, straining and excessive back motion. The need for a considerable postoperative period of restricted activity has been quite clearly indicated.

Traumatic internal derangements of the knee have been encountered quite frequently in military practice. From them one lesson, in particular, has been given emphasis. That is the necessity of preserving the stability of the knee joint by meticulous care in protecting the capular ligaments (especially the internal lateral ligament) from injury. The value of preoperative conditioning by exercise of the muscles about the knee joint, especially the quadriceps femoris, has been demonstrated in promoting earlier recovery and restoration of function after surgery.

About the matter of pilonidal disease there has also been a crystallizing of opinion. It is apparent that a policy of operative removal of every such defect discovered will not pay dividends in conservation of time and comfort. The self-regulating mechanism of civil life which deters the victim of such a defect from consulting his surgeon unless sufficient discharge or the development of inflammation renders him so uncomfortable as to seek relief, can be counted upon to control any excessive performance of the operation for removal of the lesion. In such cases as may require removal because of repeated inflammation, opinion is still somewhat divided between open and closed procedures. In appropriate cases, especially with the help of penicillin, the closed method has undoubtedly produced many excellent early results. Elaborate flap and plastic closures have gone out of fashion.

*Surgical Complications.*—Certain surgical complications have been successfully combated by measures which, already known, have shown their value in the intensive experience of war-time practice. Thus, most surgeons have become convinced of the desirability of intubation drainage in dealing with postoperative pulmonary atelectasis. The early postoperative institution of bed exercises and deep breathing have shown merit as preventive measures. The general use of spinal as opposed to inhalation anesthesia seems to have shown little effect on the incidence of this complication. In pneumonitis penicillin has time and again proven its value.

Similarly, a better understanding of peripheral phlebothrombosis has been disseminated. Most Army surgeons are now trained closely to observe their wounded and postoperative patients for the early detection of the swelling, calf tenderness and pain on plantar foot flexion that betoken the onset of clotting in the deep leg veins, and, finding them, to forestall the deadly threat of embolism by early femoral vein ligation.

Another contribution is the development of the treatment of bedsores.

Recognition and correction of their contributing causes—pressure, starvation, hypoproteinemia, soiling, dehydration, anemia and avitaminosis—sets the stage for their definitive treatment. Cleansing, protective dressings and the rapid disposal of slough, sometimes with the help of urea crystals or granulated sugar or both, prepares the sore for closure by wire sutures after undermining and approximation of the skin edges. Systemically administered penicillin, before and after operation, contributes to the complete and clean healing that occurs in nearly 65 per cent of cases thus treated.<sup>14</sup>

*Materials.*—The exigencies of war-time surgery have stimulated the development and popularized the use of a number of materials which will contribute much to the welfare of patients in civilian peace-time practice. The brilliant researches of the laboratory in the fractionation of blood proteins have given us serum albumin, so valuable in shock and protein deprivation. They have provided fibrin foam so effective as a local hemostatic agent, particularly in neurosurgery and in dealing with vascular visceral structures, especially the liver; fibrin film, useful as a tissue protective and replacement agent, especially for the scarred or injured dura; and thrombin-fibrinogen glue used in peripheral nerve suturing and skin grafting.<sup>15</sup> Tantalum has been popularized as a nonreactive, electrically inert, yet strong and workable material as wire for sutures, plates for bone defects, and foil for protection of delicate tissues.<sup>16</sup> The general use of nonabsorbable sutures of wire, cotton and silk has won many converts and has set the surgical style for at least a generation to come. Acrylic (methyl methacrylate resin) has been developed as a strong, light, nonreactive and nonsoluble material for the making of dentures, eyes and prosthetic appliances useful in plastic surgery.

*Supportive Measures.*—In dealing with large numbers of seriously ill and injured patients in war-time there has been developed a fresh appreciation of the importance of certain general supportive measures to be employed not only as a postoperative procedure and in protracted illness, but as means of prevention of deterioration and as means of preoperative preparation. In this direction, in addition to a recognition of the need for nutritive factors, fluid and electrolytes, new emphasis has been placed on the necessity of forestalling and controlling vitamin deficiency states. The effects of the avitaminoses on nutrition, wound healing and resistance to infection have been made increasingly clear. Correspondingly, there is a more general appreciation of the effects of fatigue, sepsis and malnutrition in producing the vicious circle of avitaminosis. The values of the B-complex of C and D have been repeatedly demonstrated in preventing and correcting such situations, and of K in the prophylaxis and control of hemorrhagic states.

The importance of maintaining nitrogen balance is now more fully appreciated and the means for correcting its lack are at hand in plasma, serum, albumin and the amino-acid preparations. The supportive and corrective values of repeated blood transfusions have been reaffirmed, and additional safeguards for this type of therapy have been developed especially in the recognition of the importance of the Rh factor.<sup>17</sup> The red cell by-product

of the plasma production program has found increasing use, employed in suspension in the restoration of hemoglobin deficiencies<sup>18</sup> and, in the hands of some surgeons, seems to have been beneficially utilized locally in open-wound dressings.

*Reconditioning.*—By no means the least valuable contribution of war surgery is a new concept of the value of a rehabilitation program. Faced by the need of conserving manpower, the Army rapidly began a plan of reconditioning the hospitalized soldier the object of which was to restore him to health and vigor and return him to military duty with the least waste of time. This program's activities begin with the patient still in bed and as soon after operation as his condition will permit. General bed exercises are given, and special exercises prescribed for restoration of the affected part. Thus, the patient with a leg lesion receives not only exercises of arms, trunk, neck and back, but is drilled specifically in the quadriceps setting exercises which serve to prevent weakness and restore muscle and joint function even though he be confined to bed. In certain types of cases, notably internal derangements of the knee, these special exercises have been given preoperatively, as a prophylactic preparation, with great benefit. It is the universal impression, as the result of experience, that such bed exercising, both general and special, have hastened recovery, shortened bed rest and hospitalization and have tended greatly to diminish the incidence of pulmonary and thrombotic vascular complications.

The program of exercise and increasing directed physical activity has been pursued after the patient has left his bed, through remedial and corrective calisthenics and gymnastics, occupational therapy adapted to his particular needs, and recreational activities. This program has been worked out with care and diligently pursued to the point where the patient, fully restored, has been made ready to resume his duties, after minimum hospitalization. The benefits of this war-developed practice have been so fully demonstrated as to affect profoundly our attitude toward the management of patients in peace-time practice, and throw into sharp contrast the general neglect of such measures in the past.<sup>19</sup>

This program of reconditioning has not involved the patient's physical status alone. Recreation, instruction, amusement, the development of new skills and hobbies, the stimulation of new interests and a new outlook have played a large part in it. The importance of this phase of rehabilitation, particularly as it applies to the permanently handicapped, can hardly be overemphasized. The feeble and tentative efforts hitherto made in this direction for our civilian patients will undoubtedly be greatly increased and strengthened in the future as the result of war experience.

In presenting this general summary and review no attempt has been made to cover the many technical details and refinements of procedure that have developed in various commands and hospitals as the result of war experience. It is not intended to convey the impression that the advances achieved have been due solely to war nor to the activities of Army surgeons alone. Many

had already been instituted and perfected in civilian hospitals and laboratories, and had even been quite widely recognized. It is fair to say, however, that the experiences of war have led to a more rapid proving and evaluation of their merits, the acceptance of some and the rejection of others. Certainly the school of war-time surgery has served to disseminate rapidly throughout the body of the profession a considerable fund of information which, in the long run, cannot but work to the profit of peace-time practice.

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## A STUDY OF SHOCK IN BATTLE CASUALTIES

MEASUREMENTS OF THE BLOOD VOLUME CHANGES  
OCCURRING IN RESPONSE TO THERAPY

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THE PATHOGENESIS OF TRAUMATIC SHOCK is generally recognized to be a reduction of the circulating blood volume. An essential feature of modern shock treatment is the correction of this deficiency by the transfusion of injectable protein-containing fluids. Recognizing the need for prompt transfusion therapy in the care of battle casualties, the United States Army Medical Corps has consistently made available to all medical units adequate supplies of human plasma. The efficacy of plasma transfusions in the treatment of traumatic shock has been firmly established through wide experience with its use during the present war; there is no question but that its provision to the armed forces has been responsible for the survival of countless battle casualties, and has effected an unprecedented improvement in the prognosis of serious war wounds.

Early in the war the hope was entertained that the transfusion of plasma alone would prove to be effective therapy for the vast majority of patients suffering from traumatic shock, and it was presumed that whole blood would enjoy a relatively restricted use, indications for its employment being restricted to a small percentage of extremely severe cases. However, limitations in the effectiveness of plasma as a sole replacement medium have since become apparent. It was the experience of many surgeons operating at the front in the African and Sicilian campaigns, that a considerable proportion of patients in severe shock failed to respond adequately to plasma transfusions, death occurring preoperatively or in the course of operation.<sup>1</sup> This type of case appeared to respond more favorably to the transfusion of whole blood in addition to plasma.

Throughout the Normandy campaign, in contrast to the earlier situation, large amounts of refrigerated whole blood were supplied to the Field and Evacuation Hospitals. The relative quantities of whole blood used during this period were considerably in excess of the anticipated requirements. A statistical survey of Field Hospitals in July, 1944, at the time of the intense fighting in the vicinity of St. Lo, indicated that the total amounts of whole blood and plasma administered to nontransportable casualties through the first



postoperative day averaged 1,250 cc. of whole blood and 750 cc. of plasma per patient. These cases had received an average of 550 cc. of plasma in the Battalion Aid Station or Clearing Station prior to their admission to the hospital; the final ratio of whole blood to plasma given, therefore, averaged 1:1. The unexpectedly high proportion of whole blood required raised the question as to whether its preferential use by the field surgeons was dictated on the basis of sound indications or, possibly, on false impressions.

A preliminary study was carried out by the authors during July, 1944, on 55 nontransportable patients treated in Field Hospitals. This study was restricted to serial determinations of the hemoglobin concentration and arterial pressures, with relation to the clinical condition and course, in response to therapy. The data obtained indicated that the magnitude of the blood loss sustained by patients exhibiting signs of severe shock was substantially greater than had been generally appreciated. A striking anemia was commonly present at the conclusion of therapy, despite massive whole blood transfusions. It was obvious from the results that whole blood was not being utilized to excess; indeed, the data suggested that possibly even more should be administered for optimum therapeutic results than was the customary practice.

A second investigation was then planned, the purpose of which was to accumulate more detailed and precise data pertaining to the pathologic physiology of traumatic shock with especial reference to the therapeutic problems involved. This study was carried out on a series of severely wounded casualties treated in a Field Hospital during the campaign on the German border in September, 1944. In addition to clinical observations, measurements were made of the plasma volume, hematocrit reading and plasma protein concentration, before and after therapy and, in some instances, pre- and postoperatively. This program of investigation was devised in the hope of providing definitive answers to the following questions:

1. The degree of blood volume deficit associated with shock, and the extent to which clinical signs can be correlated with varying grades of oligemia.
2. The degree of spontaneous hemodilution occurring following extensive hemorrhage.
3. The relative importance of whole blood and plasma loss, and the total blood loss resulting from various types of war wounds.
4. The magnitude of blood loss attendant on various surgical procedures.
5. Relative requirements for whole blood and plasma in shock therapy, and the effect of transfusions on the blood volume.
6. Causes of therapeutic failure in the treatment of traumatic shock.

#### TYPE OF PATIENTS AND PLAN OF STUDY

All patients reported in these series belong to the group of "nontransportable" battle casualties: patients who, because of the location or severity of their wounds, require prompt definitive treatment in a Field Hospital. One group, comprising 57 such cases, was subdivided as follows: 21 patients

with penetrating wounds of the abdomen; 15 with penetrating chest wounds; seven with combined chest and abdominal wounds; nine with extremity wounds alone; and five with extremity wounds combined with penetrating wounds of the chest or abdomen. On this group, determinations of the plasma volume, hematocrit reading and plasma protein concentration were made. The arterial blood pressures and pulse rates were measured at frequent intervals, and the clinical course was carefully described in each case.

Less detailed laboratory investigation was conducted on a series of 55 additional patients. In this group, the hemoglobin concentration was determined before and after shock therapy, the arterial pressure, pulse rate and clinical manifestations being carefully followed throughout. This group is subdivided as follows: There were eight patients with penetrating abdominal wounds, 13 with penetrating chest wounds, eight with combined chest and abdominal wounds, seven with extremity wounds alone, and 21 with extremity wounds combined with penetrating wounds of the abdomen or chest.

Seventy-three per cent of the casualties in these series were due to shell fragment wounds, 24 per cent were caused by gunshot wounds, and 3 per cent by the explosion of mines. The majority of cases were seen within six hours following injury. The patients selected for study either presented clinical evidences of shock, or had wounds of such severity that a considerable blood loss was deemed probable. Most had received preliminary shock treatment in the form of plasma transfusion before admission to the Field Hospital.

#### LABORATORY METHODS

The plasma volumes were determined by the dye method of Gibson and Evans,<sup>2</sup> adapted to the Klett photo-electric colorimeter. Plasma protein concentrations were calculated on the basis of specific gravity, using the copper sulfate method of Phillips, Van Slyke, *et al.*<sup>3</sup> Hematocrit readings were obtained after rapid centrifuging of oxalated blood samples in 4-cc. hematocrit tubes. The acid-hematin method was employed for the estimation of hemoglobin concentrations, using the Sahli-Hellige hemoglobinometer. All determinations were made exclusively on venous blood, obtained without stasis. The femoral vein was selected for venepuncture in all cases of shock.

Certain modifications of technical procedure were necessary in order to adapt these methods to the limited facilities available in a Field Hospital, and to render the tests practicable in the face of urgent therapeutic requirements. Determination of the plasma volume involved the taking of serial samples of venous blood over a period of 40 minutes. Inasmuch as a delay of 40 minutes in instituting transfusion therapy was unwarranted in many instances, the following routine was adopted:

Immediately upon admission of the patient to the shock ward, 5 cc. of venous blood were removed to serve as the dye-free sample and for the hematocrit reading, following which the dye was promptly injected. If severe shock was present a plasma transfusion was then initiated and continued during the 20-minute period required for the intravascular mixing of the dye. The amount of plasma administered during this period varied between 250 and 500 cc. During the succeeding 20-minute interval, when serial specimens were taken for determination of the disappearance curve of the plasma-dye concentration,

the transfusion was discontinued. Calculation of the initial plasma volume entailed a correction for the amount of plasma administered during the mixing period.

Blood samples were introduced into a 4-cc. hematocrit tube containing 0.2 cc. of a solution of sodium chloride in a concentration of 0.85 Gm. per cent, ammonium oxalate, 1.2 Gm. per cent, and potassium oxalate, 0.8 Gm. per cent. This solution causes no swelling or shrinkage of the red cells, and, after correcting for the 0.2 cc. increase in plasma volume due to the anticoagulant solution, the same hematocrit and specific gravity readings are obtained as with the use of dried mixed oxalate, recommended by Phillips, Van Slyke, *et al.* The advantages in using the solution of mixed oxalate in isotonic saline are, that it is unnecessary to engage in the time-consuming process of drying an aqueous oxalate solution in the tubes to prepare them for use; and, most important for the determination of plasma-dye concentration, no hemolysis is caused by the anticoagulant solution, whereas it is unavoidable in the presence of the dried mixture.

The tubes containing the blood and anticoagulant solution were placed in a portable electric angle centrifuge (Gomco Surgical Mfg. Co.) and rotated at high speed for one-half hour. Maximal packing of the cells was obtained by this procedure, and, contrary to expectations, little difficulty was encountered in reading the cellular volume since the upper level of the cell layer tends to assume a horizontal position if the tube is allowed to stand vertically for a few minutes. The hematocrit reading having been obtained, the supernatant plasma was pipetted off for the determination of plasma protein and dye concentrations. This procedure utilized the minimum of equipment, and the preparation of glassware was reduced to a point that was quite practical under the conditions imposed.

As a standard for comparison between the results reported in this investigation and the expected "normal" values for hematocrit reading and plasma protein concentration, the figures reported by Phillips, Van Slyke, *et al.*,<sup>3</sup> were used. On the basis of their study of 20 normal men, the average normal hematocrit reading is considered to be 46.9; the average normal plasma protein concentration is accepted as 6.63 Gm. per cent. The data obtained by Gibson and Evans<sup>4</sup> on 49 normal males was used to compute the expected normal plasma volume in each case reported in this communication. It should be pointed out that there is a considerable individual variation in plasma volume, irrespective of surface area. Hence, the percentage reduction in blood volume calculated for any given individual on the basis of the "normal" value, predicted from the surface area, may be in considerable error. However, a sufficiently large number of cases have been studied in this series to lend validity to such a comparison.

The hematocrit reading is utilized in calculating the total blood volume and total red cell volume from the plasma volume. This calculation is based on the assumption that the proportion of cells to plasma is the same in vessels of all caliber, an assumption that is probably incorrect. There is considerable evidence to suggest that in normal individuals the cell-plasma ratio is lower in the small vessels.<sup>5, 6</sup> This circumstance leads to an estimated error of approximately 20 per cent in calculating red cell volumes on the basis of plasma volume and hematocrit reading. To further complicate the situation, there is evidence that in shock the cell-plasma ratio in the small vessels is actually increased over that in the large vessels, owing to erythrostasis.<sup>7</sup> At any rate, caution must be exercised when comparison is made between the values accepted as normal for the total blood volume and total red cell volume, and those computed from the plasma volume and hematocrit reading of a patient suffering from shock. The absolute error inherent in the estimation of total blood volume in shock cases is, however, not of great significance; the red cell volume is so reduced that even a very considerable percentage error results in but a small error in the total volume. Assuming a 20 per cent error in computing a red cell volume of 800 cc., the resultant miscalculation amounts to only 160 cc. in the total blood volume. However, in order to reduce the inaccuracies inherent in comparing the total blood volume calculated for patients in shock with

## SHOCK IN BATTLE CASUALTIES

TABLE I  
INITIAL DATA ON FIFTY BATTLE CASUALTIES ADMITTED TO A FIELD HOSPITAL

Case No.	Diagnosis and Outcome*	Hours Since Injury	Transfusions		Arterial Pressure Mm. Hg.	Pulse Rate	Plasma Protein Gm. %	Hemat.	Blood Volume		
			Plasma Cc.	Blood Cc.					Plasma Cc.	Total Cc.	Deficit %
1	Gunshot wd. perforating rectum, colon and small bowel. Died 12 hrs. postop.	3	500	0	65/40	104	6.3	41.5	2230	3810	30
2	Shell fragment wds. of abdomen; lacerations of colon and kidney. Died 30 hrs postop.	5	1150	1250	60/40	124	5.3	32.4	2440	3610	37
3	Gunshot wd. through rt. chest; hemothorax; compound fracture of femur. Survived.	4	500	0	100/60	116	5.7	36.5	2430	3830	27
4	Gunshot wd. of rt. chest, sucking. Survived.	4	250	0	80/60	108	6.0	41.7	1790	3070	33
5	Shell fragment wds., multiple, both thighs. Survived.	3	1150	0	100/60	136	6.1	29.5	1880	2660	42
6	Mine wds. penetrating abdomens; multiple intestinal perforations. Survived.	3	750	0	130/70	104	6.6	38.4	2740	4440	6
7	Gunshot wd. penetrating rt. chest. Survived.	4	0	0	85/60	92	6.5	48.1	2730	5260	9
8	Shell fragment wd. through rt. chest. Died 12 hrs. postop.	2	0	0	80/40	140	6.0	46.4	1860	3470	31
9	Gunshot wds., with compound fractures of humerus, mandible and zygoma. Survived.	2	0	0	70/40	130	5.1	38.5	2130	3450	37
10	Shell fragment wds. perforating lung, diaphragm and liver; multiple wds. of thigh and buttock. Died immediately postop.	6	1000	500	50/40	140	5.9	29.4	1910	2700	46
11	Shell fragment wds. perforating duodenum, colon, liver and gallbladder. Died 0.5 hrs. postop.	4	350	0	55/45	140	6.5	32.1	1660	2450	48
12	Shell fragment wds. with traumatic amputation of leg; perforation of cecum. Survived.	4	1150	500	70/35	140	5.9	27.6	1660	2340	52
13	Shell fragment wd. penetrating left chest. Survived.	3	0	0	120/70	112	6.3	47.0	2830	5340	11
14	Gunshot wd. through abdomen; multiple perforations, colon and small bowel; compound fracture of ilium. Died 48 hrs. postop.	5	500	0	60/40	124	5.8	32.8	2170	3230	30
15	Shell fragment wd. through lt. chest; extensive laceration lt. upper lobe. Died 5 hrs. postop.	2	750	0	75/20	112	5.9	32.9	1790	2670	47
16	Shell fragment wd., with perforation of duodenum and inferior ven cava. Died 0.5 hrs. postop.	2	250	0	85/40	128	6.4	31.8	2160	3160	42
17	Mine wds. penetrating abdomen; multiple small perforations and mesenteric lacerations. Survived.	3	500	0	85/50	160	6.5	36.5	1630	2560	48
18	Gunshot wd. through axilla, severing brachial artery and vein. Survived.	3	750	0	70/40	124	5.9	27.4	2200	3030	46

TABLE I—(Continued)  
INITIAL DATA ON FIFTY BATTLE CASUALTIES ADMITTED TO A FIELD HOSPITAL

Case No.	Diagnosis and Outcome*	Hours Since Injury	Previous Transfusions			Arterial Pressure Mm. Hg.	Pulse Rate	Plasma Protein Gm. %	Hemat.	Blood Volume		
			Plasma Cc.	Plasma Cc.	Blood Cc.					Plasma Cc.	Total Cc.	Deficit %
19	Shell fragment wd., with compound fracture of femur; urethral transection. Survived.	5	500	0	0	80/55	128	6.2	33.7	2230	3420	44
20	Gunshot wd. penetrating rt. chest, sucking. Survived.	2	500	0	0	70/50	132	6.0	28.6	2130	2990	47
21	Shell fragment wd. penetrating abdomen; liver lacerated. Survived.	5	250	0	0	100/70	80	7.3	39.6	2580	4270	16
22	Shell fragment wd. penetrating lt. chest; hemothorax. Survived.	2	0	0	0	50/0	140	6.0	44.2	2140	3840	27
23	Shell fragment wds. penetrating abdomen; lacerations of liver and kidney; compound fracture of femur. Survived.	5	250	0	0	40/30	128	6.9	35.4	1830	2840	41
24	Shell fragment wd., sucking, rt. chest; hemothorax; perforation, diaphragm and liver. Survived.	3	750	0	0	65/25	140	5.6	27.5	1920	2550	46
25	Shell fragment wd. penetrating abdomen; multiple small bowel perforations. Survived.	2	0	0	0	100/60	96	6.9	47.3	2840	5380	4
26	Gunshot wd. penetrating rt. chest; hemothorax. Survived.	1	0	0	0	120/80	116	6.4	43.8	2080	3710	15
27	Shell fragment wd. penetrating abdomen; liver laceration. Survived.	3	0	0	0	130/80	180	6.5	49.1	2670	5250	3
28	Gunshot wd. of thigh, lacerating femoral artery and vein. Died 5 hrs. after admission.	8	1400	500	500	50/0	120	5.2	16.3	2390	2860	46
29	Shell fragment wd. through chest and abdomen; hemothorax; lacerations of diaphragm, spleen and kidney. Survived.	5	1000	0	0	95/50	144	6.1	28.4	2180	3050	32
30	Shell fragment wd., abdominal, with perforation of colon and eversion. Survived.	4	250	0	0	95/60	140	6.5	44.0	2520	4500	9
31	Shell fragment wds., with compound fractures of humerus, scapula and clavicle. Survived.	3	500	0	0	100/65	110	6.0	38.1	2490	4030	23
32	Shell fragment wd. penetrating rt. chest; hemothorax. Survived.	2	250	0	0	120/75	88	7.0	48.2	2430	4700	9
33	Shell fragment wd. penetrating abdomen; no visceral perforations. Survived.	3	250	0	0	110/70	88	6.4	44.0	2580	4600	13
34	Shell fragment wds. penetrating abdomen; multiple perforations of colon and small bowel; wds. of arm, face and scalp. Died 14 hrs. postop.	2	500	0	0	140/90	96	6.6	45.5	2050	3760	24

## SHOCK IN BATTLE CASUALTIES

TABLE I—(Continued)  
INITIAL DATA ON FIFTY BATTLE CASUALTIES ADMITTED TO A FIELD HOSPITAL

Case No.	Diagnosis and Outcome*	Hours Since Injury	Previous Transfusions			Arterial Pressure Mm. Hg.	Pulse Rate	Plasma Protein Gm. %	Hemat. Cc.	Blood Volume		
			Plasma Cc.	Blood Cc.	Plasma Cc.					Total Cc.	Deficit %	
35	Gunshot wd. through abdomen, perforating colon. Survived.	2	500	0	0	120/80	96	6.5	46.3	2050	3820	24
36	Shell fragment wd. penetrating abdomen; multiple perforations of bladder and small bowel. Comp. fracture of coccyx. Survived.	3	0	0	0	110/70	80	6.5	46.0	2000	3700	22
37	Shell fragment wd. of lt. chest, sucking. Survived.	1	0	0	0	90/70	120	6.3	36.0	1940	3040	25
38	Gunshot wd. through lt. flank with laceration, lt. kidney. Survived.	4	0	0	0	80/65	76	6.4	38.2	1900	3040	35
39	Shell fragment wd. penetrating abdomen, with multiple perforations of small bowel and colon. Died 12 hrs. postop.	5	1000	0	0	50/40	80	5.4	26.4	1850	2520	51
40	Shell fragment wd. penetrating lt. chest; hemothorax. Survived.	7	500	0	0	65/50	108	6.9	37.0	2270	3610	26
41	Shell fragment wd. penetrating abdomen; laceration of spleen. Survived.	3	0	0	0	170/90	80	6.2	49.0	3040	5950	2
42	Shell fragment wd. penetrating lt. chest; lacerations of diaphragm and liver; hemothorax. Survived.	5	0	0	0	140/70	108	6.1	41.5	2140	3660	25
43	Shell fragment wds., multiple, arm and thigh. Survived.	3	0	0	0	100/70	120	6.2	40.2	2710	4550	5
44	Shell fragment wds. penetrating abdomen; multiple perforations, small bowel, colon and bladder. Died 8 hrs. postop.	2	0	0	0	90/80	104	6.0	53.2	1760	3760	22
45	Gunshot wd. through rt. chest; hemothorax. Survived.	?	500	0	0	90/70	132	6.1	39.8	2170	3600	24
46	Shell fragment wd. penetrating chest; lacerations of diaphragm and liver; hemothorax. Survived.	1	0	0	0	65/40	112	5.9	34.1	2040	3100	32
47	Shell fragment wds. penetrating abdomen and buttock; multiple perforations of small bowel; compound fracture, rt. ilium. Died 12 hrs. postop.	2	500	0	0	0/0	140	5.8	37.0	1840	2920	39
48	Mine wds., multiple, with compound fractures of rt. femur, rt. and lt. tibia and fibula, and rt. radius. Died 5 hrs. after admission.	6	750	0	0	60/0	100	5.4	24.2	1810	2390	51
49	Shell fragment wd. penetrating thorax; cord transection. level T-V. Survived.	5	500	0	0	70/50	80	5.7	39.2	2880	4740	0
50	Shell fragment wd. penetrating thorax; cord transection, level T-II. Survived.	3	1250	0	0	85/60	88	6.2	34.2	4200	6390	18% excess

"normal" values, 9 per cent has been arbitrarily subtracted from the values reported by Gibson and Evans for normal males. Using their figures, altered in this fashion to compensate for the error in red cell volume, it is considered that the total blood volumes determined for patients in severe shock stand valid comparison with the volumes estimated to be normal for these individuals.

## RESULTS

### I. CLINICAL MANIFESTATIONS OF BLOOD VOLUME DEFICIENCY

Detailed clinical and laboratory data, obtained on 50 battle casualties upon their admission to the Field Hospital, are recorded in Table I. This series includes all patients whose blood volumes were determined at the time of hospital entry. From the figures obtained a correlation was attempted between the arterial pressure and pulse rate, on the one hand, and the percentage deficit in total blood volume on the other.

*The Arterial Pressure.*—Figure 1 illustrates the relation between the systolic arterial pressure and the blood volume deficit in 48 patients with war wounds and varying degrees of shock. It is apparent that all cases with a systolic arterial pressure below 85 mm. of mercury had a diminution in blood volume of more than 25 per cent. All cases with a systolic arterial pressure exceeding 100 mm. of mercury showed a deficit in blood volume of less than 25 per cent. Thus, it may be stated that, whereas, the absence of hypotension does not preclude the presence of a considerable degree of oligemia, a systolic pressure persisting at a level below 85 mm. of mercury is definite evidence of a very grave deficiency in blood volume.

Blood volume determinations were made in 23 patients whose systolic pressures were below 85 mm. of mercury; the average blood volume deficit in these cases was 40 per cent. It should be pointed out that all cases examined were first seen several hours after their injuries were incurred, so that hypotension on the basis of syncope, peripheral vascular collapse or "neurogenic shock" due to temporary vasomotor influences, did not play an important rôle. None of the cases included in Figure 1 had sustained injuries to the central nervous system. Two cases with signs of spinal cord transection in the upper thoracic region (Cases 49 and 50) showed definite hypotension in the absence of significant blood volume deficiency, probably as the result of sympathetic paralysis.

*The Pulse Rate.*—The correlation between pulse rate and diminution in blood volume is not striking (Fig. 2.) Rates exceeding 130 per minute were generally associated with a marked decrease in blood volume; on the other hand, several cases with severe oligemia exhibited no tachycardia whatever.

Other clinical signs commonly associated with shock, such as pallor of the skin, coldness of the extremities and mental changes, proved to be unreliable indices of blood volume deficiency. Cold extremities and pallor were present almost universally on arrival of the wounded patients in the hospital, due, to some extent at least, to the influence of pain and exposure to cold.

### II. ALTERATIONS IN HEMATOCRIT READING, HEMOGLOBIN CONCENTRATION AND PLASMA PROTEIN CONCENTRATION ASSOCIATED WITH SHOCK

Determination of either the hemoglobin concentration or the hematocrit

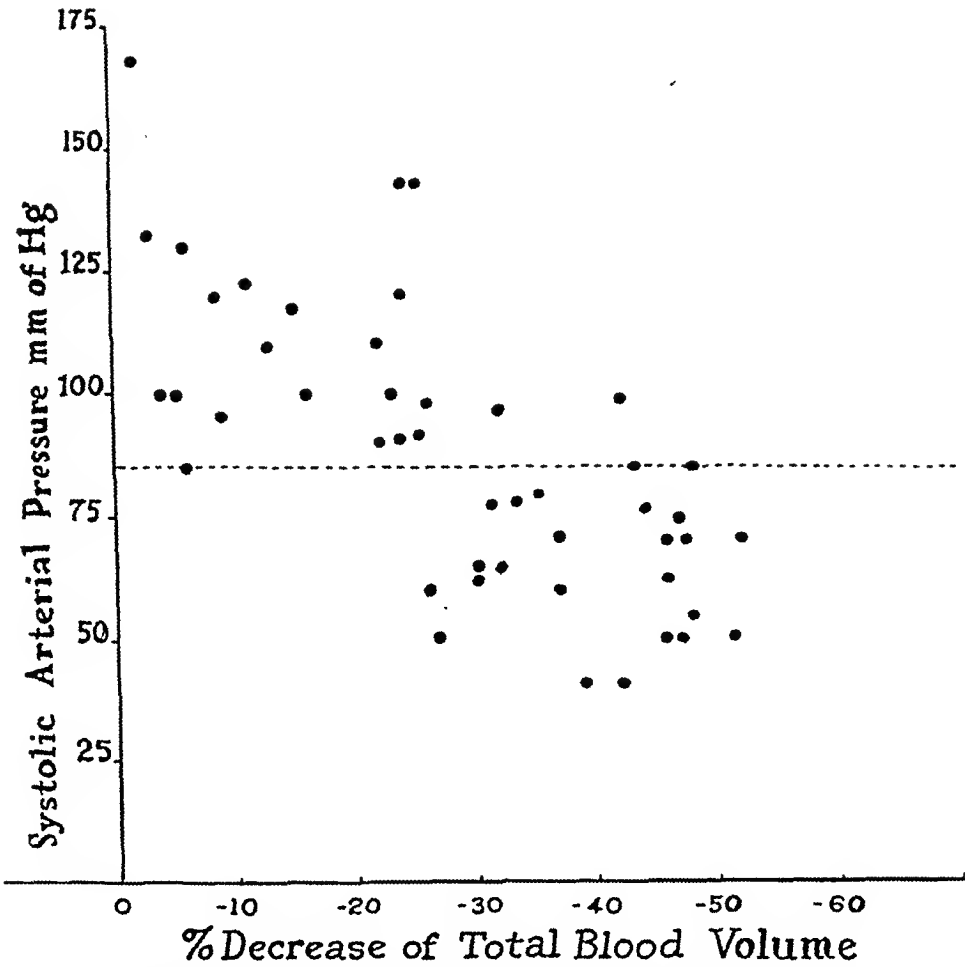


FIG. 1.—The relationship between systolic arterial pressure and blood volume deficit in 48 seriously wounded battle casualties before hospital therapy.

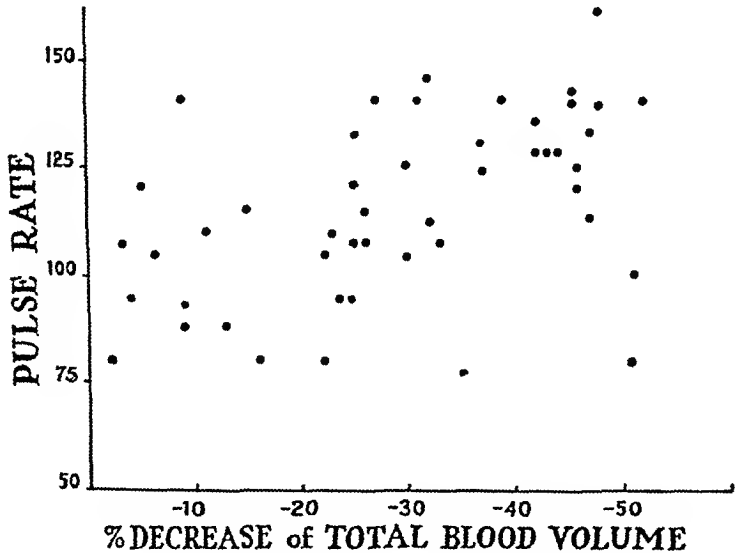


FIG. 2.—The relationship between pulse rate and blood volume deficit.

Data was obtained from the same group of 48 patients represented in Figure 1. No consistent correlation between pulse rate and degree of oligemia is observed.



reading were performed in 94 patients with severe war wounds. The results are plotted in Figure 3.

Anemia, indicating some degree of hemodilution, was found in the great majority of cases. Definite erythroconcentration was encountered in but one instance (Case 44, Table I). Almost all patients received in severe shock, *i.e.*, whose arterial pressures were less than 85 mm. of mercury, had some degree of anemia. The amount of plasma administered to the patient prior

### Plasma Received Prior to Admission

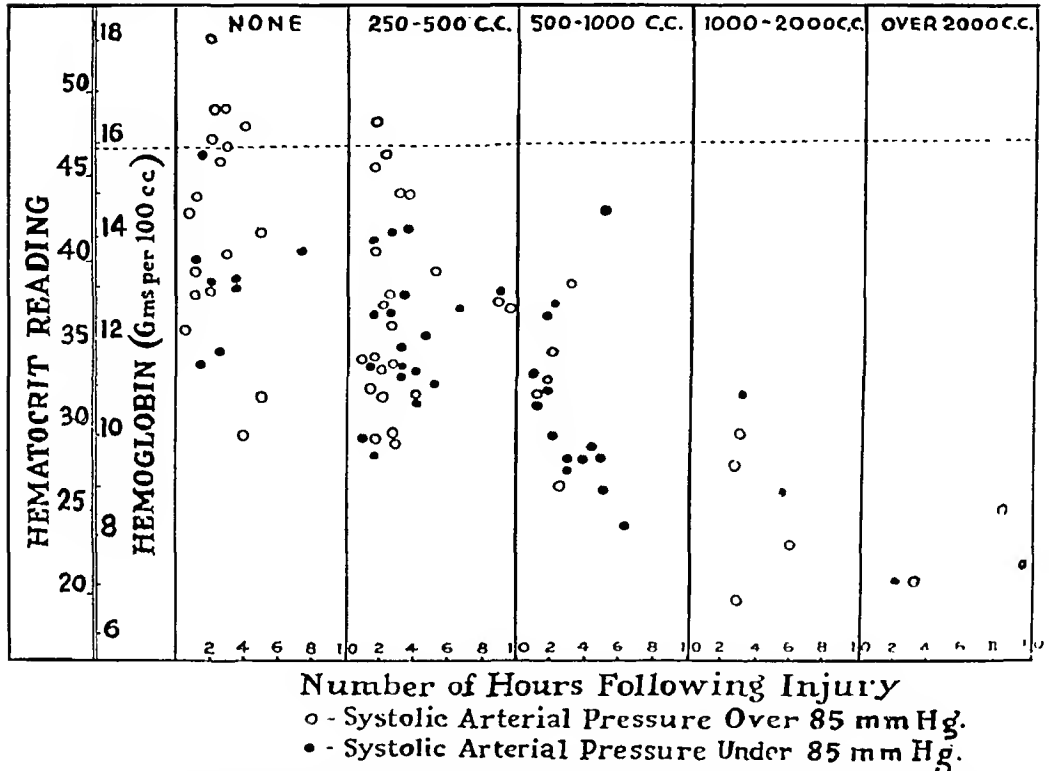


FIG. 3.—The degree of anemia observed in 94 casualties on admission to a field hospital. The dotted line represents the approximate average hemoglobin concentration and hematocrit reading for normal adult males of this age-group. Spontaneous hemodilution of moderate degree occurred in the majority of the cases who had bled severely. It is evident that marked anemia is produced by the injection of plasma in large quantities.

to hospital admission was a potent factor in those who had received this material, unsupplemented by whole blood, in volumes exceeding 1,000 cc. There was no definite correlation between the degree of anemia and the length of the time-interval following injury, or the type of wound incurred.

The plasma protein concentration was measured in 50 cases at the time of hospital admission (Table I). The values ranged between 5.1 and 7.3 Gm. per cent. A concentration below 5.5 Gm. per cent was encountered in only five instances. There was no consistent correlation between the degree of hypoproteinemia and the degree of shock. The results indicate that in the majority of cases spontaneous hemodilution with protein-free fluid had occurred in the interval between injury and hospitalization, but that the degree of hemodilution was not great. The maximum volume of such fluid calcu-

lated to have entered the circulating blood was 450 cc., and only in rare instances does it appear to have exceeded 200 cc.

### III. RELATIVE LOSSES OF PLASMA AND RED CELLS, AND THE ESTIMATED TOTAL BLOOD LOSS ASSOCIATED WITH VARIOUS TYPES OF WOUNDS

The relative losses of red cells and plasma can be estimated from the ratio of the hematocrit reading and the plasma protein concentration. If whole blood is lost from the vascular system and hemodilution with protein-free fluid occurs, the hematocrit reading and protein concentration decrease proportionately. If plasma alone is lost, or if the plasma loss is disproportionately high, the ratio of plasma protein concentration to hematocrit reading is low. This relationship is illustrated in Figure 4.

Few cases showed evidence of pure, or markedly disproportionate, plasma

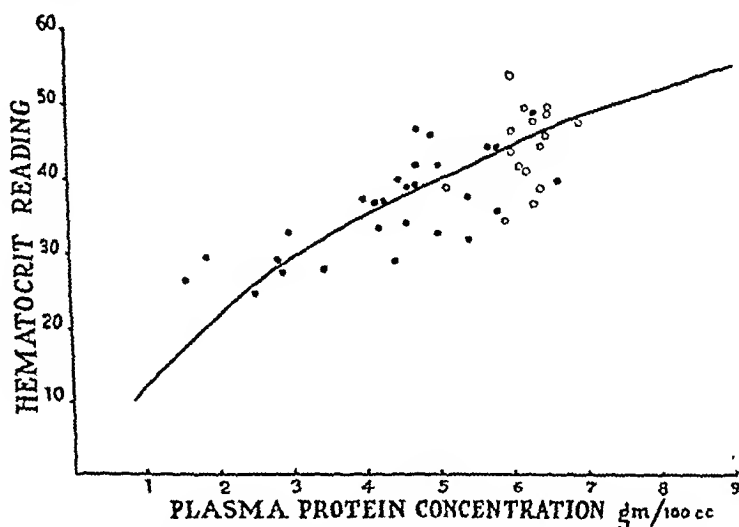


FIG. 4.—The relative loss of plasma and red cells incurred by 44 battle casualties.

The curved line represents the ratio between hematocrit reading and plasma protein concentration with progressive dilution of normal blood by protein-free fluid. Solid dots represent patients who had received plasma, their plasma protein values having been corrected for the injected protein; circles denote patients who had received no transfusion therapy. Points above the line indicate a disproportionate loss of plasma; those below the line indicate either plasma protein regeneration or erythro-concentration in the capillary bed.

loss. Case 44 (see Table I) is the most striking instance in which this phenomenon apparently occurred. This particular patient was admitted with an hematocrit reading of 53.2, and a plasma protein concentration of 6.0 Gm. per cent, having received no transfusions prior to entry. At operation he was found to have multiple perforations of the bowel and bladder; the peritoneal cavity was filled with urine and feces. Similar findings were obtained in Cases 34 and 35; both of these patients, likewise, had penetrating wounds of the abdomen with multiple perforations of the colon.

Inasmuch as the majority of cases had received plasma before admission to the hospital, the blood volume deficit determined at that time does not represent the total amount of blood lost. Knowing the volume of plasma received prior to admission, the extent of the hemorrhage can be estimated with reasonable accuracy from the calculated deficit in total circulating protein.

TABLE II  
CHANGES IN BLOOD VOLUME EFFECTED BY TRANSFUSION THERAPY

Case Type* (No.)	Hours After Entry	Volume Transfused			Arterial Press. Mm.Hg.	Plasma Protein Conc. Gm. %	Hemat.	Blood Volume		Increase in Red Cell Vol.		Increase in Plasma Protein		Estimated Blood Loss During Therapy Cc.
		Plasma Cc.	Blood Cc.	Diluent† Cc.				Plasma Cc.	Total Cc.	Expected Cc.	Found Cc.	Expected Gm.	Found Gm.	
Abd.	0				65/40	6.3	41.5	2230	3810					
(1)	2.5	250	2500	2500	150/80	6.0	41.6	3660	6270	1250	1030	105	80	600
Abd.	0				60/40	5.3	32.4	2440	3610					
(2)	3.5	250	2000	2000	110/84	5.3	36.0	4000	6250	1000	1080	87	83	0
Chest	0				98/60	5.7	36.5	2430	3830					
(3)	3.5	0	1500	1500	140/66	5.5	37.9	3570	5740	750	770	53	58	0
Ext.	0				70/44	5.1	38.5	2130	3450					
(9)	8.5	250	2000	2000	138/75	5.3	36.7	3450	5450	1000	670	105	75	900
Ext.-Chest	0				50/40	5.9	29.4	1910	2700					
(10)	5.5	500	2750	1250	90/60	6.4	34.9	3270	5010	1375	950	131	97	1000
Abd.-Ext.	0				55/45	6.5	32.1	1660	2450					
(11)	5	400	2000	2000	124/70	5.6	35.5	2750	4260	1000	720	98	46	1100
Ext.	0				70/35	5.9	27.6	1660	2340					
(12)	6	350	1800	600	126/78	6.2	32.6	3200	4750	900	870	87	100	0
Abd.	0				62/38	5.8	32.8	2170	3230					
(13)	3	250	2000	2000	100/50	5.8	36.5	3680	5800	1000	1060	87	87	0
Abd.-Ext.	0				85/40	6.4	31.8	2160	3160					
(14)	0	500	2000	2000	140/50	6.5	34.0	3800	5750	1000	890	105	108	0
Ext.	0				70/42	5.9	27.4	2200	3030					
(16)	3	500	2000	2000	148/84	5.8	31.0	2870	4160	750	460	87	36	1100
Ext.	0				78/54	6.2	33.7	2230	3420					
(18)	5	500	1500	1500	138/78	5.5	31.0	3380	4900	750	330	81	48	1000
Ext.	0				70/50	6.0	28.6	2130	2990					
(19)	4	450	1500	2000	112/72	6.1	33.5	3710	5580	1000	1010	105	98	0
Abd.-Chest	0				100/70	7.3	39.6	2580	4270					
(20)	5	500	2000	1000	122/70	7.3	40.2	3380	5650	500	580	53	58	0
Abd.	0				40/30	6.9	35.4	1830	2840					
(21)	6	250	1000											
Abd.	0													

# SHOCK IN BATTLE CASUALTIES

TABLE II (Continued)  
CHANGES IN BLOOD VOLUME EFFECTED BY TRANSFUSION THERAPY

Case Type* (No.)	Hours After Entry	Volume Transfused			Arterial Press. Mm.Hg.	Plasma Protein Conc. Gm. %		Hemat.	Blood Volume		Increase in Red Cell Vol.		Increase in Plasma Protein		Estimated. Blood Loss During Therapy Cc
		Plasma Cc.	Blood Cc.	Diluent† Cc.					Plasma Cc.	Total Cc.	Expected Cc.	Found Cc.	Expected Gm.	Found Gm.	
(23) Chest-Abd.	6:5	250	2000	2000	110/75	6.2	38.0	38.0	3420	5510	1000	1080	88	86	0
(29) Ext.	0	0	2000	2000	96/48	6.1	28.4	28.4	2180	3050	1000	650	70	50	700
(31) Chest	4	250	2300	2300	128/88	5.8	32.2	32.2	3200	4720	1150	560	98	65	1100
(37) Chest-Abd.	0	0	1000	1000	100/65	6.0	38.1	36.0	2490	4030	500	530	35	43	0
(38) Abd.	2	250	1150	550	126/70	6.1	36.0	36.0	3520	5500	570	600	57	67	0
(39) Chest	0	250	2500	2500	90/70	6.3	36.6	36.6	1940	3040	1250	1350	105	93	0
(40) Chest	3	500	1350	450	150/105	5.9	38.2	38.2	2820	4450	675	570	82	65	350
(46) Abd.	4	0	2000	2000	80/66	6.4	36.5	36.5	1900	3040	1000	830	70	80	0
(47) Ext.	0	500	2500	2500	50/40	5.4	26.4	26.4	3040	4800	1250	1380	122	91	520 (plasma)
(48)	4	0	2350	1450	156/86	5.9	39.2	39.2	3270	5300	1170	1050	82	68	400
					65/50	6.9	37.0	37.0	2270	3610					
					110/58	6.8	36.8	36.8	3270	5170					
					65/40	5.9	34.1	34.1	2040	3100					
					138/100	6.3	37.5	37.5	3160	5050					
					0/0	5.8	37.0	37.0	1840	2920					
					80/60	6.1	43.0	43.0	3270	5730					
					60/0	5.4	24.2	24.2	1810	2390					
					102/20	4.9	32.6	32.6	3380	5010					

\* Location of the major wound: (Abd.—abdominal; Ext.—extremity.

† Glucose—citrate—saline solution used as red blood cell preservative.

This deficit, in the 23 cases of severe shock whose blood volumes were measured at the time of admission, averaged 63 per cent. The blood volume deficiency in the majority of these patients represented a loss of plasma and red cells in approximately equal proportions; therefore, the protein deficit determined in this group can be assumed to represent an average blood loss of 63 per cent of the original total blood volume, or approximately 3,000 cc. Six patients (Cases 2, 5, 10, 12, 28 and 39) had sustained an estimated blood loss of over 80 per cent of their normal volumes before admission to the Field Hospital, life having been sustained by plasma transfusions exceeding 1,000 cc. in volume, supplemented in three cases by transfusions of whole blood.

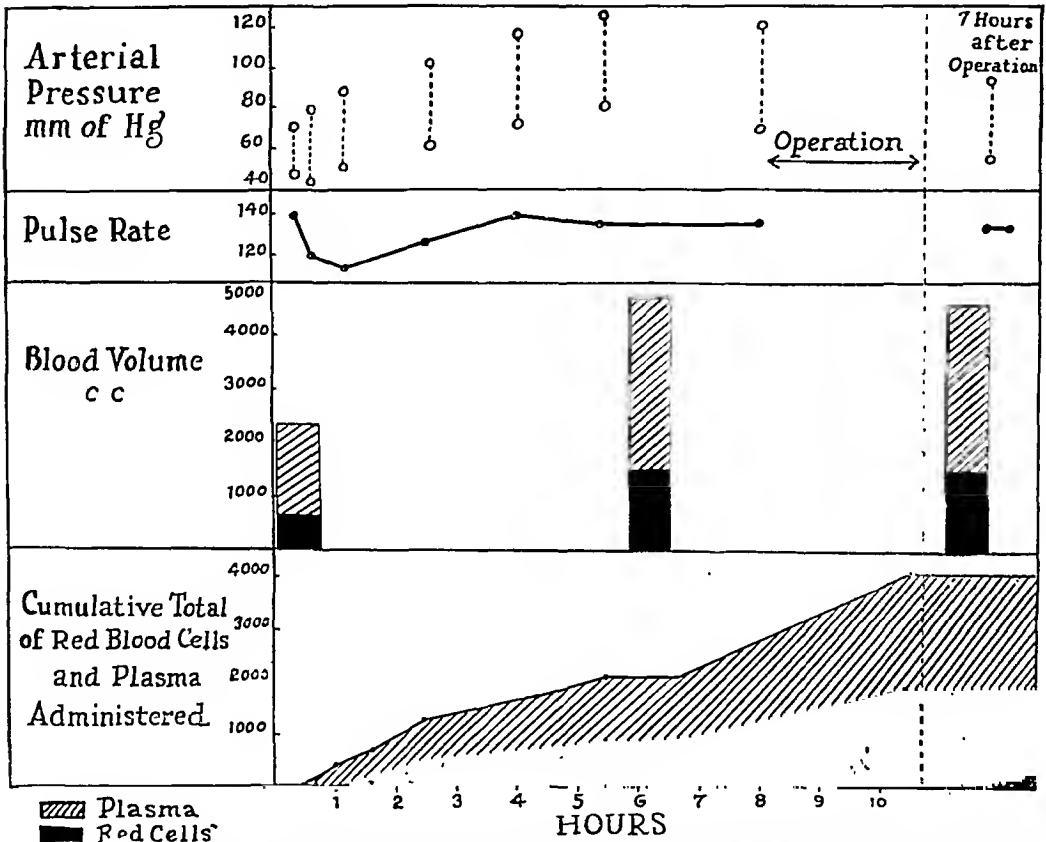


FIG. 5.—Changes in blood volume effected by transfusion therapy and surgical operation (Case 12). This patient was admitted in severe oligemic shock which was corrected by transfusion. An estimated loss of 2,600 cc. of blood occurred during operation, which included repair of a cecal laceration and débridement of peripheral wounds.

The most excessive blood loss occurred in the patients with extremity wounds, only one of whom—a patient with multiple small soft-tissue shrapnel wounds—had bled less than 40 per cent of his estimated total blood volume. Six patients with extremity wounds, complicated by perforating wounds of the abdomen or chest, lost an average of 70 per cent of their blood volume; seven cases with extremity wounds alone lost 60 per cent. The average total hemorrhage occurring between the time of injury and admission to the hospital was least in the group with perforating chest wounds, uncomplicated by abdominal or extremity wounds. This group comprised 12 patients who

were studied from this point of view; their average loss was estimated to be 35 per cent. Nineteen patients with abdominal wounds alone lost an average of 40 per cent, and the hemorrhage in four cases with combined abdominal and chest wounds averaged 50 per cent of their expected normal total blood volume.

#### IV. BLOOD LOSSES DUE TO SURGICAL PROCEDURES

The degree of hemorrhage complicating various operative procedures in traumatic surgery varies widely depending upon the extent and type of operation performed, as well as on the care that the surgeon can afford to devote to hemostasis. It was thought to be of interest to measure the loss occurring during the surgical repair of various types of war wounds, as carried out under Field Hospital conditions. Accordingly, blood volumes were determined pre- and postoperatively in ten cases (Table III), and the volume of blood given during operation was ascertained. Five of the operations involved celiotomy, with repair of bowel perforations; in one case (see Fig. 5) the operation included débridement of multiple extremity wounds. The series includes three open thoracotomies with repair of diaphragmatic and hepatic lacerations, one amputation of an arm combined with thoracotomy, and one débridement of multiple wounds of thigh and foot.

The average blood loss in the five celiotomies was 2,200 cc.; in the three thoracotomies, 600 cc. The blood loss in the case with amputation of an arm and thoracotomy was estimated to be 3,200 cc. It is apparent from even this small series of cases that the blood loss complicating extensive débridements, and the repair of perforating abdominal wounds is frequently of such magnitude as to require vigorous replacement therapy during operation.

#### V. RESPONSE TO THERAPY

Fifty-five cases of severe shock were treated by the authors. The majority of these patients responded to preoperative transfusion therapy by exhibiting a satisfactory rise in arterial pressure. Only three cases, representing 5 per cent of the cases studied, failed to respond in this fashion. The average volume of whole blood and plasma administered prior to operation was 2,650 cc. The ratio of whole blood to plasma was 2.3 to 1.0, this ratio being determined to a large extent by the availability of whole blood; thus, in the series of cases studied during the campaign in Germany, after large quantities of whole blood had been made available, the ratio of the whole blood and plasma used in the hospital for preoperative preparation of these battle casualties approached six to one. The average total volume of plasma and blood required to produce an elevation of arterial pressure from below 85 to above 100 mm. of mercury was 1,250 cc. No consistent alteration in pulse rate was observed in response to transfusion therapy.

Serial determinations of the plasma volume, total circulating protein and hematocrit reading were performed in the course of transfusion therapy in 23 cases (Table II). Predicted increases in red cell volume and total circulating protein are based on data derived from testing numerous samples of the plasma and stored blood used in treatment; the plasma protein content

per 250-cc. unit of dried plasma, and that contained in 500 cc. of undiluted whole blood, averaged approximately 17.5 Gm., the average hematocrit reading of the stored blood, correction having been made for the added preservative-diluent solution, was approximately 50.

Twelve cases showed an increase in red cell volume and total circulating protein that corresponded very closely with the values expected on the basis of the amounts transfused. There were 11 patients, however, in whom it is apparent that blood loss must have persisted during the course of shock therapy. The individual losses in these cases ranged from 350 to 1,100 cc., or between approximately 20 and 50 per cent of the blood and plasma transfused. Such losses occurred with greatest regularity in patients with extremity wounds, seven out of a total of ten such patients suffering a loss which averaged 40 per cent of the blood and plasma received. Two of six abdominal cases continued to bleed after admission, their losses averaging approximately 600 cc., or 20 per cent of the volume transfused; in one of these (Case 47), several hours after the patient had incurred multiple perforations of the small bowel, the material lost during therapy appears to have consisted exclusively of plasma.

There was no obvious relation between the phenomenon of continued hemorrhage and the degree of oligemia present at the time therapy was begun. Neither the initial blood pressure nor the pulse rate proved helpful in the diagnosis or prediction of continued hemorrhage; thus, of those patients who continued to bleed during therapy, 80 per cent had been in shock at the time of their admission, whereas signs of shock were present in 70 per cent of those whose bleeding had ceased. Persistence of hemorrhage, likewise, appeared to bear no relation to the amount of blood and plasma administered prior to admission, the average amounts received by the persistent bleeders and the others having been practically identical.

Almost all of the blood employed in the treatment of these cases was diluted with an equal volume of glucose-sodium citrate-saline preservative (Alsever's solution). Patients requiring the transfusion of large amounts of blood were, therefore, obliged to receive, in addition, large volumes of crystalloid solution, the amounts of which are recorded in Table II. The effect of this therapy, with respect to the degree of hemodilution produced, may be gauged by observing the resultant changes in the plasma protein concentration; the latter, together with the plasma volume and hematocrit reading, was measured in all cases within 30 minutes, and in most cases within ten minutes following the conclusion of the transfusion. As is evident from inspection of Table II, surprisingly little accentuation of hypoproteinemia was produced by the injection of large volumes of dilute blood, the plasma protein concentration of which averaged approximately 2.3 Gm. per cent. The circulating plasma protein concentration after transfusion was less than 5.5 Gm. per cent in only three patients (Cases 2, 9, and 48), and in each of these cases the concentration was less than 5.5 before transfusion. In no instance was the hematocrit reading substantially reduced, although that of

most of the blood given was approximately .25; the occurrence of any reduction whatever was almost invariably associated with continuance of hemorrhage during the transfusion. It may be concluded, therefore, that retention of the blood-diluent solution, even when injected rapidly in quantities exceeding 2,000 cc., is not of sufficient duration or magnitude to promote significant hemodilution in the recipient.

#### VI. ANALYSIS OF THERAPEUTIC FAILURES

Table IV summarizes the mortality statistics for the entire series of 112 battle casualties observed by the authors. All deaths are recorded which occurred preoperatively, during operation and within 24 hours postoperatively. A few deaths occurred later than the first postoperative day, but it is not

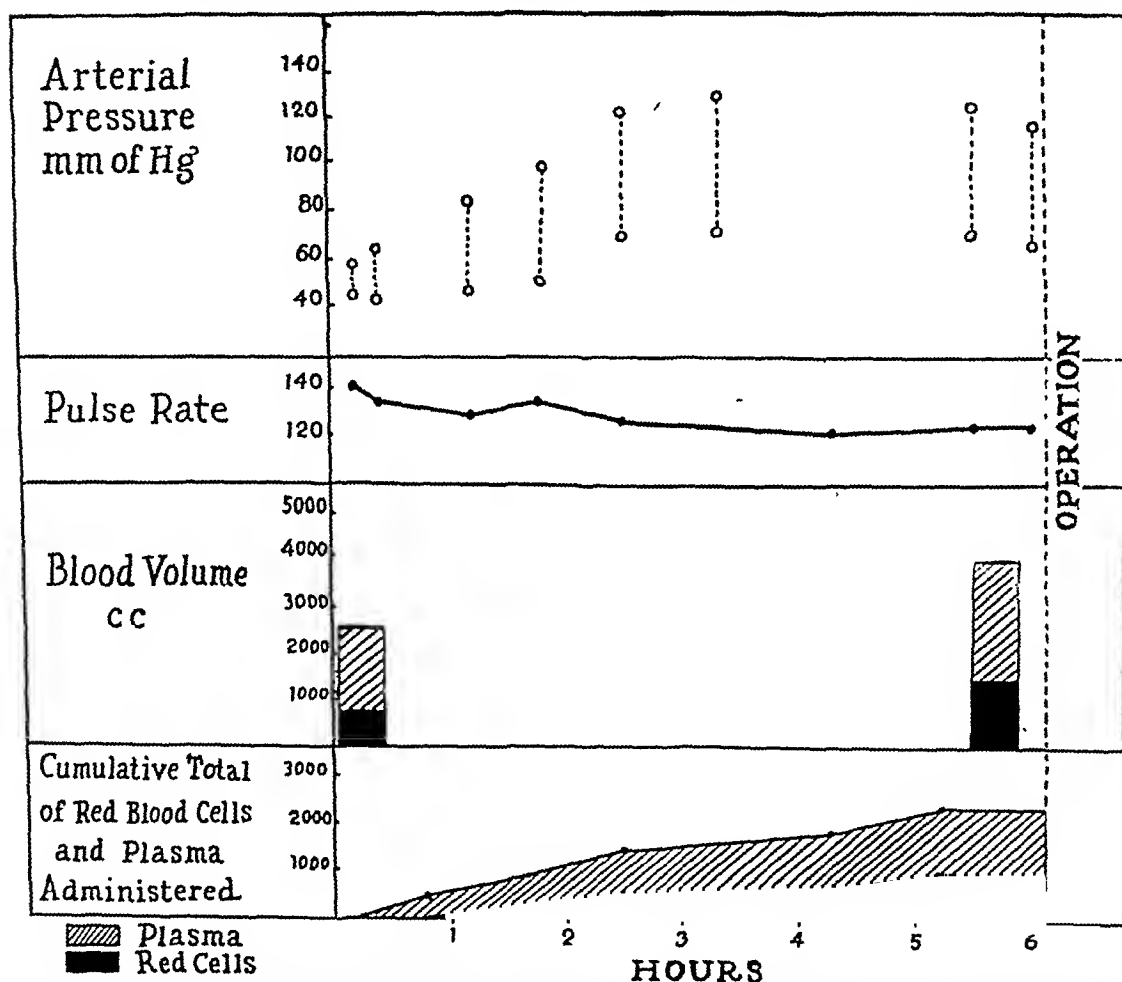


FIG. 6.—Effect of transfusion on the blood volume in a case with persisting hemorrhage (Case 11). This patient, with perforations of duodenum and colon, compound fracture of humerus, and thigh wounds, received 2,400 cc. of blood and plasma, of which 1,100 cc. is estimated to have been lost during therapy.

considered that they were attributable to failure of shock therapy or preoperative preparation of the patient. The mortality incidence in 55 cases admitted with systolic arterial pressures over 85 mm. of mercury was 11 per cent, representing six cases in this group; of these six patients, five died as a result of penetrating abdominal wounds with intestinal perforation. Of the 57 patients admitted in severe shock, *i.e.*, with arterial pressures less than 85 mm. of mercury, there were 18 deaths, a mortality incidence of 32 per cent.



It is of considerable interest to analyze the factors apparently responsible for therapeutic failure in the cases which failed to survive. For the purposes of this analysis, only those patients who had received careful laboratory investigation, as well as clinical study, are discussed. Of the 57 cases in which blood volume measurements were made, 13 deaths occurred within the first postoperative day. Eight of these 13 patients (Cases 1, 11, 16, 34, 39, 44, 47 and 57) died as a result of penetrating wounds of the abdomen; one died without operation, two died during or immediately following surgery, and five approximately 12 hours postoperatively. The initial response to shock therapy was good in all cases. Excepting one case, the amount of blood transfused prior to operation appeared adequate to restore the blood volume to normal. In one patient (see Fig. 6) some hemorrhage obviously occurred during therapy, and blood volume was decreased at the time of operation.

Two patients (Cases 11 and 16) died on the operating table. The wounds, in one case, included perforation of the inferior vena cava and transection of the duodenum; in the other, there were extensive lacerations of the liver, duodenum and transverse colon. These deaths were considered to be due to excessive, uncontrollable blood loss during operation.

The six remaining fatalities are attributable to peritonitis. Two of these cases are of particular interest in that, despite adequate shock therapy, there occurred a secondary fall in arterial pressure before surgical intervention was possible.

Case 57 (Fig. 7) was admitted to the hospital five hours after receiving a gunshot wound penetrating the right lower abdomen. A moderate degree of shock had responded satisfactorily to the previous transfusion of 1,500 cc. of blood and plasma. Four hours after admission, however, despite an additional transfusion of 1,300 cc. of whole blood, the systolic arterial pressure dropped to an average level of 60 mm., and diastolic to 40 mm. of mercury. One hour later the blood volume was determined and found to be normal, in view of which no more blood or plasma was given.

The patient gradually developed an ashen cyanosis. The skin became cold, dry and mottled in appearance; blanching, which lasted for several seconds, could be produced by momentary pressure at any point. The abdomen was tense and exquisitely tender. The chest was normal on physical and roentgenologic examination. Restlessness became increasingly marked, but the patient complained of no pain or discomfort and remained entirely lucid. During his sixth hour in the hospital, the arterial pressure ceased to be obtainable. The femoral pulse, still palpable, became irregular, the rate averaging 130 beats per minute. The blood volume was again measured; the results were substantially the same as those obtained three hours previously, indicating that no further intra-abdominal hemorrhage had occurred during this interval.

Nine hours after entry the patient died. Postmortem examination revealed extensive lacerations of the cecum and ascending colon, and multiple perforations of the ileum; the abdominal cavity was filled with blood and intestinal contents. It is apparent, in this case, that the terminal fall in arterial pressure, culminating in severe shock and death, was unrelated to a diminution of blood volume, but was due to massive peritoneal contamination.

Case 47 (Fig. 8) illustrates a good initial response to shock therapy, with a secondary fall in arterial pressure in spite of a sustained normal blood volume. The findings at operation included multiple perforations of the rectum, colon and small bowel with generalized peritonitis, and a compound fracture of the ileum. The postoperative course

# SHOCK IN BATTLE CASUALTIES

TABLE III  
BLOOD VOLUME CHANGES RESULTING FROM MAJOR OPERATIVE PROCEDURES IN THE TREATMENT OF BATTLE CASUALTIES

TABLE III ROLLING FROM MAJOR OPERATIVE PROCEDURES IN THE TREATMENT OF BATTLE CASUALTIES												
Case No.	Operative Procedure	Transfused During Operation		Time	Plasma Protein Conc.	Hemat. Gm. %	Blood Volume			Estimated Blood Loss During Operation		
		Blood Cc.	Plasma Cc.				Plasma Cc.	Total Cc.	Red Cells Cc.	Plasma Cc.	Total Cc.	
1	Celiotomy; 2 ft. of jejunum resected; colostomy; multiple perforations of small bowel and rectum repaired.	1500	250	preop.	6.0	41.6	3660	6270	680	2070	2750	
12	Celiotomy; cecum repaired; débridement of wds., rt. flank and rt. leg.	2000	0	postop.	5.1	44.0	3420	6100				
44	Celiotomy; colostomy; perforations of small bowel and bladder repaired.	1500	750	preop.	6.2	32.6	3200	4750				
34	Celiotomy; 18 inches of jejunum resected; portion of colon exteriorized.	1500	0	postop.	5.8	34.4	2940	4490				
51	Celiotomy; portion of ileum resected; multiple perforations of jejunum repaired; portion of descending colon exteriorized.	540	0	preop.	4.9	53.2	1760	3760	1000	1630	2630	
52	Thorocotomy; laceration of rt. lung repaired; hemothorax drained. Rt. arm amputated.	1550	0	postop.	6.6	31.2	2490	3620	1620	1650	3270	
53	Thorocotomy; rib resection; foreign body removed from hilus, right lower lobe; hemothorax drained.	0	0	preop.	5.9	45.4	2050	3760				
54	Thorocotomy; 3000 cc. of blood evacuated from wd. of liver sutured; diaphragm repaired.	1000	0	postop.	6.6	44.9	2220	4060	620	950	1570	
55	Thorocotomy; penetrating wd. of diaphragm sutured.	0	0	preop.	6.3	49.9	2260	4500	130	760	890	
56	Débridement of penetrating wds. of lt. thigh and foot.	500	250	postop.	5.7	32.8	3310	4920				
				preop.	5.4	30.7	2530	3650	1270	1930	3200	
				postop.	6.3	42.0	2930	5050				
				preop.	6.2	41.8	2780	4770				
				postop.	5.6	38.7	3380	5510	130	210	340	
				preop.	5.2	35.2	3750	5800				
				postop.	...	42.3	3240	5620	580	540	1120	
				preop.	6.9	43.7	2830	5020				
				postop.	5.7	33.8	3380	5100	190	....	440	
				preop.	5.8	30.9	3240	4680	570	700	1270	

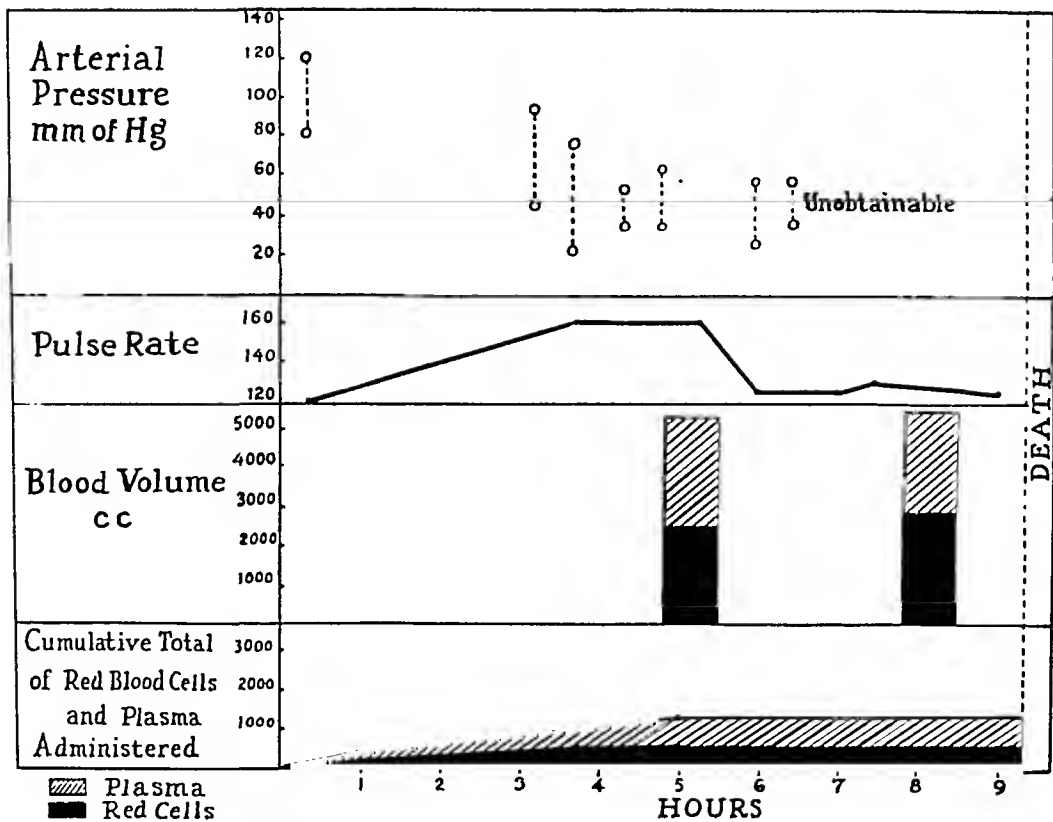


FIG. 7.—Shock due to peritonitis in a patient without oligemia. (Case 57; see case report)

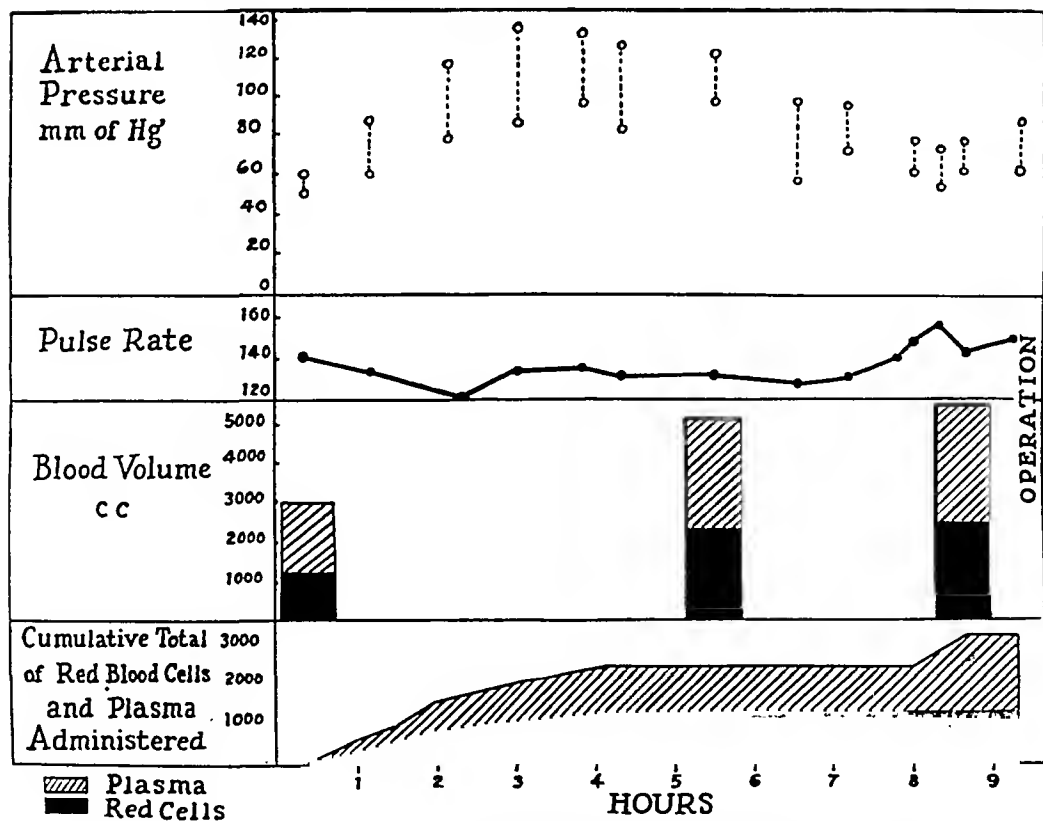


FIG. 8.—Recovery from oligemic shock with subsequent fall in arterial pressure due to peritonitis (Case 47).

Patient was admitted in severe shock, with penetrating abdominal wounds. Correction of the initial oligemia was followed by satisfactory rise in arterial pressure, which, however, was unsustained despite a normal and stable blood volume.

was marked by persistent hypotension and progressively severe shock, terminating in death 11 hours after operation.

The four remaining fatalities due to abdominal wounds also died in shock approximately 12 hours postoperatively. The recurring signs of shock in these patients, in contrast to Case 47, first developed after operation. This group is well exemplified by Case 1 (Fig. 9), a patient admitted in severe shock following a gunshot wound of the right buttock. Response to transfusion therapy was excellent, both with respect to clinical signs and blood volume.

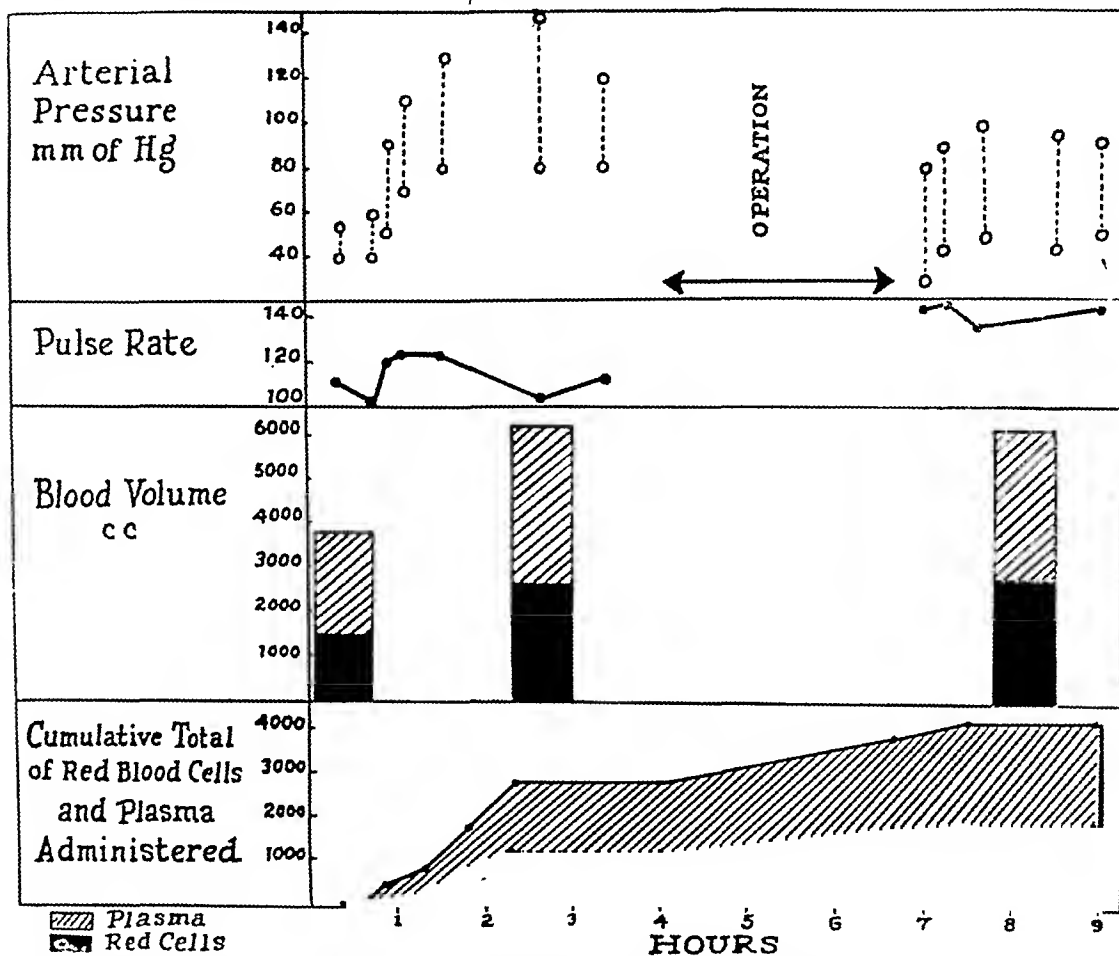


FIG. 9.—Successful treatment of oligemic shock (Case 1).

Adequate response to initial shock therapy is indicated by return of the arterial pressure and blood volume to normal. Operation, nine hours after injury, revealed multiple intestinal perforations and massive peritoneal contamination with feces. The blood volume was satisfactorily maintained, despite which there subsequently developed signs of progressively severe shock due to peritonitis.

Operation was completed six hours following admission, nine hours after injury; the abdomen was discovered to be filled with blood and feces in consequence of multiple tears and perforations involving the rectum, colon and small bowel. Immediately following operation the patient's condition was satisfactory, and a blood volume determination performed at that time yielded normal values. Twelve hours later, however, death ensued, apparently as the result of overwhelming peritoneal infection.

Blood volume studies were done on three patients with fatal wounds of the chest (Cases 8, 10, and 15). Extensive damage to lung tissue was present in all three cases. One patient died without operative intervention.

one died immediately following completion of open thoracotomy, and the other died approximately 12 hours postoperatively. Dyspnea and cyanosis, due to lack of functioning lung tissue, consistently dominated the clinical picture. The response to transfusion therapy was disappointing, the arterial pressure tending to remain moderately depressed despite a normal blood volume. The patient who died prior to operation developed terminal pulmonary edema, and death in all three cases appeared to be the result of pulmonary damage with consequent inadequate blood oxygenation, and not due primarily to circulatory failure.

The two patients who died as a result of extremity wounds presented features of unusual interest.

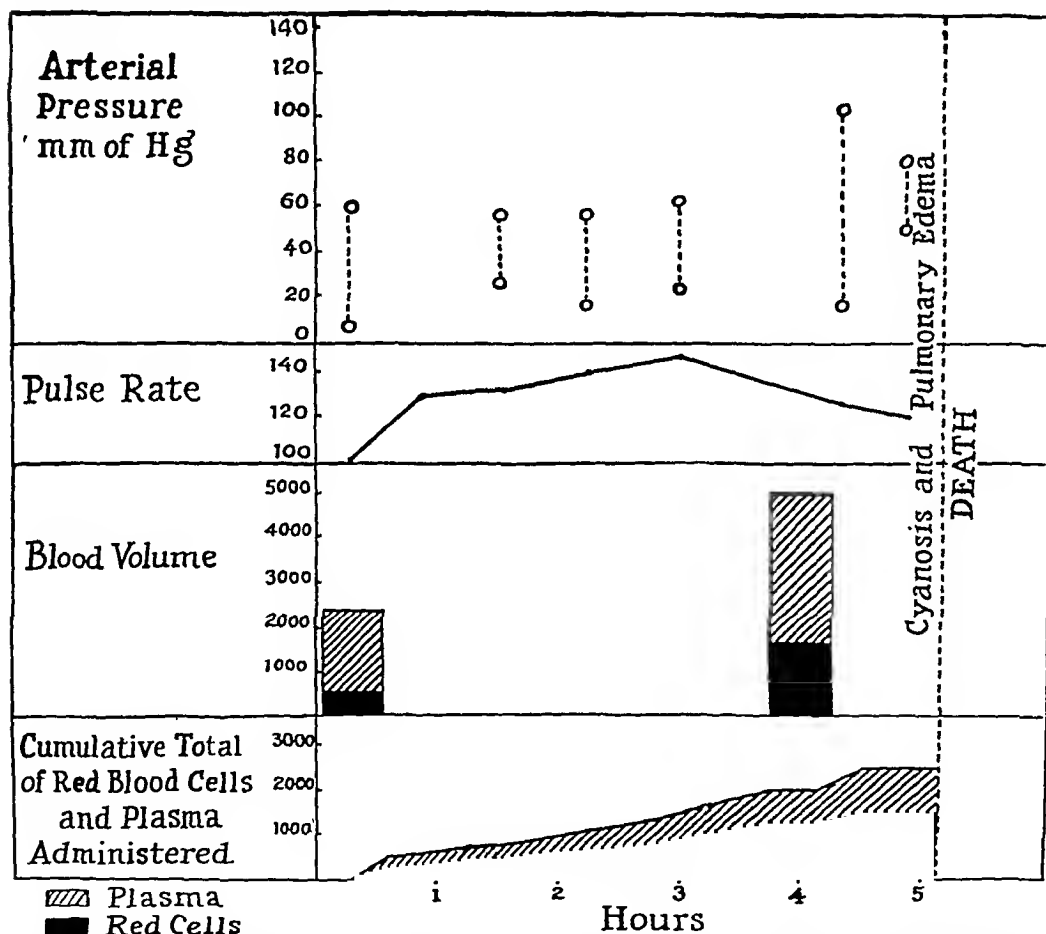


FIG. 10.—Failure of shock therapy following prolonged oligemia, anemia and hypertension (Case 48).

The patient was admitted to the hospital six hours after sustaining multiple compound fractures of both legs. Correction of the oligemia not only failed to alleviate shock, but precipitated signs of venous hypertension and pulmonary edema.

Case 28 was admitted with a through-and-through gunshot wound of the thigh, incurred seven hours previously. Despite having received 1,900 cc. of blood and plasma before entry he was in severe shock, manifested by coma, pallor and coldness of the skin, and a systolic arterial pressure of 50 mm. of mercury. Blood volume studies indicated not only a marked oligemia, but also a severe anemia, the red cell volume totaling approximately 500 cc. Following the transfusion of 900 cc. of whole blood the patient became relatively lucid; the skin became warm and acquired a pink hue,

# SHOCK IN BATTLE CASUALTIES

with a slightly cyanotic tinge. However, there was no substantial rise in arterial pressure; the maximum level was 75 mm. of mercury systolic and 35 mm. diastolic, only briefly attained after 2,000 cc. of blood had been received. Thereupon, inasmuch as the diameter of the thigh appeared to be increasing slightly, a tourniquet was placed above the wound and an additional transfusion of 2,000 cc. of blood was given. In the course of this transfusion the arterial pressure continued to fall, the sensorium again became clouded, cyanosis increased and the neck veins became distended. Five hours after admission death supervened, preceded by the development of frank pulmonary edema. Postmortem examination revealed a transection of the femoral artery and a massive hematoma in the thigh; the femur was not fractured, and there was no evidence of gas bacillus infection.

Case 48 (Fig. 10) was admitted with multiple mine wounds of both legs, including compound fractures of one femur and of both bones of both lower legs. He was received into the hospital six hours after injury. The initial laboratory studies indicated a

TABLE IV  
MORTALITY INCIDENCE IN 112 BATTLE CASUALTIES  
*Admission Systolic Arterial Pressure over 85 Mm. of Hg.*

Type of Wound	No. Survived	No. Dead*	Per Cent Mortality
Abdominal.....	15	4	21
Chest.....	12	0	0
Chest and abdominal.....	8	0	0
Extremity.....	4	0	0
Extremity and chest.....	6	1	14
Extremity and abdominal.....	4	1	20
Total.....	49	6	11

*Admission Systolic Arterial Pressure under 85 Mm. of Hg.*

Abdominal.....	6	4	40
Chest.....	11	5	31
Chest and abdominal.....	5	2	29
Extremity.....	7	5	41
Extremity and chest.....	5	0	0
Extremity and abdominal.....	5	2	29
Total.....	39	18	32

\* Includes deaths occurring preoperatively, during operation, and within 24 hours after operation.

severe oligemia and anemia; the total red cell volume was approximately 600 cc. Despite adequate replacement therapy, as indicated by a return of the blood volume to normal levels, the patient never recovered from shock. There developed a livid cyanosis, neck vein distention and, terminally, frank pulmonary edema, death occurring five hours after admission.

The above cases are similar, in that both patients had been in shock for an extended period of time before effective replacement therapy could be instituted. Both had received large quantities of plasma prior to admission, and entered with severe anemia in addition to marked oligemia. These patients failed to respond to adequate shock treatment, although in neither case could this failure be attributed to lack of adequate transfusion therapy or to the presence of infection. The sequence of events suggests that failure of shock therapy in these cases is related to irreversible changes in the cardiovascular system resulting from prolonged tissue anoxia. Persistence of their arterial hypotension, with associated signs of peripheral venular stasis and, with

increase of the blood volume to normal, the appearance of progressive venous hypertension and pulmonary edema, are possibly all attributable to myocardial insufficiency.

#### DISCUSSION

The present study indicates that the shock syndrome, developing in battle casualties within a few hours after injury, is essentially a reflection of a diminished blood volume attributable to hemorrhage. The average blood volume deficit was 40 per cent in the patients who were received in severe shock. A similar degree of oligemia associated with traumatic shock has been reported by Evans.<sup>8</sup> The great majority of patients presented no evidence of excessive plasma loss, relative to the loss of red cells; a few abdominal cases were encountered in whom a disproportionate loss of plasma had occurred, seemingly in consequence of peritoneal exudation.

Most of the patients reported in this study had received plasma before admission to the Field Hospital. Many cases, having been transfused with large amounts of plasma, were admitted in severe shock which was obviously due to continued hemorrhage. In consequence of the dilution of their blood with the transfused plasma, these patients suffered a marked reduction in the oxygen capacity of the circulating blood in addition to a diminution of blood volume, a combination of deficiencies that is extremely deleterious. Oligemia was not accompanied by profound anemia in those cases which had not received plasma, from which it may be deduced that spontaneous hemodilution, at least during the first few hours after hemorrhage, plays a very minor rôle in restoration of the blood volume.

Ideal shock therapy, and the proper preparation of shock cases for surgery, entail restoration of the blood volume to approximately normal levels, and the maintenance of an adequate hemoglobin concentration in the blood. The amounts of blood and plasma required to correct the oligemia vary from case to case, and sound clinical judgment must be exercised if the therapeutic requirements are to be met properly. Blood volume measurements are obviously not practical as a routine laboratory procedure. Most clinical signs, including the rate and character of the pulse, the skin temperature and the degree of pallor, were found to be unreliable indices of oligemia. The presence of anemia, unless plasma had been received prior to admission, was found to be indicative of marked oligemia, but the progress of spontaneous hemodilution is so slow and variable that the hemoglobin determination proved of little value as a guide to transfusion therapy in the treatment of casualties received within a few hours after injury. Two criteria, however, were found to be exceedingly helpful in estimating the degree of blood volume deficiency, the first of which is the character of the wound. Certain types of wounds, such as traumatic amputations, compound fractures of large bones, severance of major blood vessels, chest wounds with signs of hemothorax and lacerations of abdominal viscera with hemoperitoneum, are almost invariably accompanied by marked oligemia. The second criterion of transfusion requirement is

the level of the arterial blood pressure. Excepting in patients with central nervous system injuries, a definite correlation was found to exist between the systolic pressure and the degree of oligemia. Patients with systolic pressures below 85 mm. of mercury were consistently found to have a blood volume deficit exceeding 25 per cent, while those with pressures greater than 100 mm. of mercury always presented less than a 25 per cent deficiency.

The following general plan of transfusion therapy was followed by the authors in treating oligemic shock and preparing casualties for surgery: Patients received with normal arterial pressures, but with severe wounds suggesting a significant degree of blood loss, were given 1,000 cc. of blood preoperatively; those patients admitted with a low arterial pressure attributable, as far as could be detected, to blood loss alone, received 2,000 cc. of blood preoperatively, or, if an adequate response was not attained, 1,000 cc. beyond that amount required to restore the systolic arterial pressure to approximately 100 mm. of mercury. Blood volume determinations at the completion of shock therapy applied in this fashion, indicated that the oligemia had been accurately corrected in most instances. Patients with perforating wounds of the chest were treated somewhat more conservatively: unless they were obliged to undergo a major operation under general anesthesia, preoperative transfusions were halted when the systolic arterial pressure had risen to approximately 100 mm. of mercury, in order to avoid precipitating further intrapulmonary hemorrhage.

During major surgical procedures, particularly in abdominal and extremity cases, further transfusion was usually required to maintain the blood volume. The degree of operative blood loss was often considerable, in some cases amounting to between 2,000 and 3,000 cc. The amount of transfusion required must obviously be calculated on the basis of the estimated blood loss incident to the surgical procedure and, more particularly, the course of the arterial pressure during operation.

The question as to the proper rôle of plasma in shock therapy is a very important one. Plasma unquestionably serves as an adequate substitute for whole blood in the restoration of a reduced blood volume. It is, therefore, an invaluable therapeutic agent in emergency shock therapy under circumstances in which whole blood is not immediately available, and in the treatment of mild or moderate oligemia as a means of conserving whole blood. However, it must be emphasized that the unrestricted use of plasma inevitably leads to anemia, when employed in the presence of oligemia; the greater the degree of oligemia, the greater is the dilution effect of transfused plasma on the remaining red cells. The use of more than 1,000 cc. of plasma in the treatment of severe oligemic shock results in a very profound anemia, which often cannot be materially improved by whole blood transfusions without dangerously overloading the circulation. It is particularly desirable to avoid this complication in patients with massive wounds. Such patients usually face the added ordeal of a prolonged general anesthesia within a few hours following injury, and the additional loss of blood during operation may be ex-



cessively great. The presence of severe anemia, with marked diminution of the oxygen-carrying power of the blood, renders these patients especially prone to develop irreversible shock, in consequence of prolonged tissue anoxia. Anemia is, likewise, a dangerous complication in patients with penetrating wounds of the chest, already suffering from anoxemia as a result of a reduction in the amount of functioning lung tissue; not only is there a lowering of the oxygen capacity of the blood but its oxygenation is deficient.

Excessive transfusion therapy should be avoided in the treatment of shock and the preoperative preparation of wounded patients. No case should receive more blood or plasma than is required to restore the blood volume to normal. Most individuals, to be sure, suffer no ill effects from transfusions which elevate the blood volume several hundred cubic centimeters in excess of normal; on the other hand, patients with any type of wound may have hemorrhage induced or enhanced by this procedure. Chest cases, with penetrating wounds of the lung, are particularly endangered by overloading of the circulation. Too vigorous replacement therapy in these patients often leads to increased dyspnea and cyanosis due to pulmonary congestion, edema and hemorrhage, complications that may prove fatal. It has been our experience that these patients respond best to slow transfusions of whole blood, the volume of which does not exceed that amount required to restore and maintain the arterial blood pressure at a safe level.

It often requires the finest clinical judgment to ascertain at what point transfusion should be stopped in the treatment of a patient in shock. Failure of the arterial pressure to rise as expected, in response to apparently adequate shock therapy, may be due to persistent oligemia on the basis of continued concealed bleeding; on the other hand, there may be other factors perpetuating or aggravating the shock, irrespective of a normal blood volume. Possible factors include infection, such as peritonitis, or a gas bacillus infection; prolonged tissue anoxia, due to oligemia and hypotension, especially when aggravated by anemia; pulmonary damage with resultant impairment of blood oxygenation, or anoxic anoxia; and, finally, failure of vasoconstriction due to lesions involving the central nervous system. As soon as it becomes evident that oligemia is no longer the factor responsible for the state of shock, further transfusions should be regarded as of no avail, and this therapy abandoned forthwith. One of the earliest indications that the replacement therapy has been more than adequate, or has been prosecuted too vigorously, is the development of neck-vein distention; on the appearance of this sign, transfusion must promptly be halted if pulmonary edema is to be averted.

#### SUMMARY AND CONCLUSIONS

One hundred and twelve battle casualties admitted to a Field Hospital with serious abdominal, chest or extremity wounds have been studied by the authors. Fifty per cent of these patients were in severe shock. Detailed clinical observations were made in all cases, and serial determinations of either the hemoglobin concentration or hematocrit reading were performed. Measure-

ments of the plasma volume and plasma protein concentration, as well as hematocrit reading, were completed in 57 cases; in 33 cases multiple blood volume determinations were made, either in the course of transfusion therapy, or before and after operation.

The arterial blood pressure was found to provide the most reliable clinical index of blood volume deficiency. All patients with initial systolic pressures below 85 mm. of mercury, excluding cases with spinal cord transection, were found to have marked oligemia, the deficit averaging 40 per cent of the expected normal blood volume; all cases with this degree of hypotension had a diminution in blood volume that exceeded 25 per cent.

Blood volume and plasma protein measurements indicated that some degree of spontaneous hemodilution with low protein fluid often occurred in cases suffering from oligemic shock; the amount of this dilution, however, was small, rarely exceeding 200 cc. It is concluded that a normal hematocrit reading, or the demonstration of a mild anemia within a few hours after injury is no indication that a severe blood loss has not occurred. Severe anemia was produced by the administration of plasma to patients with marked oligemia.

The majority of patients presented no evidence of an excessive loss of plasma in proportion to red cells; in a few cases with severe abdominal wounds there was demonstrated a disproportionate plasma loss, which resulted in a mild degree of erythroconcentration. The average total blood loss estimated to have occurred in cases of severe shock before admission to the hospital was 63 per cent. Hemorrhage appeared to have been most severe in patients with extremity wounds, and least severe in patients with uncomplicated chest wounds.

Blood volume measurements were performed pre- and postoperatively in ten cases, in order to ascertain the degree of blood loss occurring in the course of various surgical procedures. The average loss in three cases subjected to open thoracotomy was 600 cc.; five patients requiring extensive abdominal surgery lost an average of 2,200 cc. of blood.

Serial determinations of the blood volume indicated that hemorrhage occurred during the course of transfusion therapy in 11 out of 23 patients studied. This complication was encountered most commonly in patients with severe extremity wounds, a majority of these cases suffering a loss which averaged 40 per cent of the blood and plasma transfused.

Plasma protein measurements before and after the injection of blood diluted with equal volumes of preservative solution indicate that retention of the latter in the blood stream is transient, and of insufficient degree to produce significant hemodilution.

The mortality incidence in all cases admitted in severe shock was 32 per cent; of those whose arterial pressure on admission exceeded 85 mm. of mercury, 11 per cent died within a similar period, which included the first postoperative day. The majority of deaths were attributable to penetrating abdominal wounds.

Cases are described in whom the clinical signs of shock were unrelieved by therapy, despite complete restoration of the blood volume to normal. The factors operative in the production of "irreversible shock" included severe infection, lesions involving the central nervous system, anoxic anoxia due to pulmonary damage, and long-persisting combination of anemia, oligemia and hypotension, with terminal signs of myocardial insufficiency.

Therapeutic indications for the use of whole blood and plasma are cited, and criteria for evaluating the requisite amount of transfusion therapy are discussed.

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# A COMPARATIVE STUDY OF 100 FRACTURES OF THE SHAFT OF THE FEMUR IN WHICH ONE-HALF WERE TREATED WITH PENICILLIN

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DURING A PERIOD of one year's service of a General Hospital in Italy a series of 100 consecutive femoral shaft fractures have been followed from the time of their Base Hospital surgery until they were deemed able to be evacuated to the United States for rehabilitation. The cases were divided into four main groups, namely: Group I—Twenty compound fractures treated without wound closure or penicillin; and Group II—Fifty compound fractures treated with wound closure and penicillin therapy. Subdivisions of this group were provided. Group II-A—represents nine septic cases carried over from Group I. Group II-B consisted of 41 patients treated with the penicillin program before, or upon admission to this hospital; Group III—12 compound fractures treated with wound closure, but without penicillin therapy; Group IV—18 simple femoral shaft fractures. Of the compound fractures there were 79 battle casualties and three resulting from accidental injuries. Two of the 18 simple fractures were caused from mine explosions and the remainder sustained accidental fractures. The management has developed from a time when it was considered unwise to close wounds over compound fractures to a method of treatment where débrided wounds were closed, surgical drainage established and penicillin therapy routinely administered. This transition of surgical management has developed with an increased supply of penicillin and experience acquired with battle casualties. The purpose of this communication is to present a comparative study of the four groups from the viewpoint of bone and wound healing. The factors upon which this study is based include the type of wound and fracture management; the time interval elapsed before primary surgery; reparative surgery;<sup>1\*</sup> surface coverage of bone; callus formation; clinical union of bone, and wound healing; the type of Base Hospital surgery; and complications encountered and results.

Before the 82 battle casualties came under our care they had received shock therapy, including plasma and whole blood. Wound excision had been performed under ether anesthesia in an average of 16.5 hours after

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\* Colonel Edward D. Churchill, Surgical Consultant of the North African and Mediterranean Theater of Operations, introduced reparative surgery with the following statement: "A highly significant and far-reaching advance in military surgery has taken place in the Base Hospitals, with the development of what may be called reparative surgery. Wounds left unsutured at the initial operation are routinely closed by suture, usually at the time of the first dressing. With the use of penicillin as a safeguard against infection, the management of wounds complicated by fractures or joint involvement has been revolutionized."

injury. The fracture was immobilized either in a spica encasement or Tobruk splint for early evacuation. The patient arrived in comfort and without shock, with few exceptions, in an average of six days following the fracture. In most instances there were retained foreign bodies and the fragments were unreduced. They presented the most severe group of casualties among the extremity injuries. There were usually signs of moderate anemia, hyperpyrexia,<sup>2</sup> and extensive multiple wounds. Additional serious injuries of other bones, abdomen, chest and brain were not uncommon. Laboratory data revealed an average red blood count of 3,000,000, white blood count of 15,000, hemoglobin 75 per cent (11.3 Gm.), hematocrit 34.7 volume per cent, and the total serum protein 6.3 volume per cent. The latter figure is the only one which approximates normal. This is to be expected six days after injury, since the blood stream carries a small percentage of the total body proteins.

Seventy-five per cent of the compound femoral shaft fractures were severely comminuted, presenting roentgenographic evidence of involvement of two to eight inches of the bone. Fifty-one per cent were fractures of the middle third, 29 per cent of the distal third, and 20 per cent were within the upper third of the femur. Penicillin was administered to 50 cases, and 3,000 cc. of whole blood was required to restore and maintain the normal blood picture on these cases in Groups II-A and II-B. The most blood administered to any one case in this series during the course of treatment in this hospital was 9,500 cc., a septic femur in Group II-A.

Skeletal traction was the initial reparative method of alignment in the majority of cases.<sup>3</sup> Tibial traction was employed in lower and middle third femoral fractures as illustrated in Figure 1. The insertion of a second Kirschner wire through the distal femoral fragment for control of the posterior bowing at the fracture site was useful in lower third shaft fractures (Fig. 2). Usually five pounds weight is required on this wire to reduce displacement when longitudinal traction is correct. Vertical traction with a Kirschner wire through the distal femoral shaft is helpful in upper third fractures and where there are wounds to observe (Fig. 3). These cases are not maintained in vertical traction longer than four to six weeks, so as to prevent patella fixation and stretching of the quadriceps muscle. Further traction treatment is maintained with the Thomas splint and Pierson attachment. The Kirschner wire or Steinman pin can be used through the tibia when vertical traction is employed, but it is advisable to use a plaster boot to balance the weight. This method was employed in those cases who had fractures of the tibia and fibula on the affected side and two-pin fixation was chosen as the method of treatment for the leg fractures.

Surgical access to the thigh can be attained by suspending the extremity in overhead traction (Fig. 4). This is described by Major Benjamin E. Oblatz.<sup>4</sup> Figures 4-A and B show typical wounds and drainage sites. Transportation from the operating room is managed with the extremity in traction, as shown in Figure 5.



FIG. 3

FIG. 1.—Tibial traction for lower and middle third femoral shaft fractures. The extremity is suspended in a Thomas splint with Pierson attachment on a Balkan frame. Release of foot for active motion is regularly practiced.  
FIG. 2.—Tibial traction with a second Kirschner wire inserted through the distal femoral fragment used to control posterior bowing. Vertical pull of five pounds is usually required until callus is visual roentgenologically.

FIG. 3.—Vertical traction with Kirschner wire pull from the supracondylar area of the femur. External rotation, abduction and flexion of the distal fragment will reduce the upper third femoral shaft fracture. This position will allow excellent dependent drainage of the thigh in addition to accessibility of the wounds without disturbing continued traction. Patients are usually allowed to remain in this type of traction from four to six weeks then they are placed in traction as in Figure 1, without a reposition of the Kirschner wire.

FIG. 4.—Vertical traction with 90-90-90 position of the lower extremity on the operating table in preparation for surgery. Excellent surgical access to the distal femur.

FIG. 4

In those cases in which immediate open reduction was chosen as the treatment of choice, as in complicating chest injuries, rigid fixation with application of a metal vitallium or molybdenum steel plate and screws were used.<sup>5</sup> This was done through a clean surgical incision and the wounds were closed, with drainage if indicated. This is illustrated in Figure 6, which shows the wound, and in Figure 7, which shows the internal fixation.

FIG. 4A



FIG. 4B

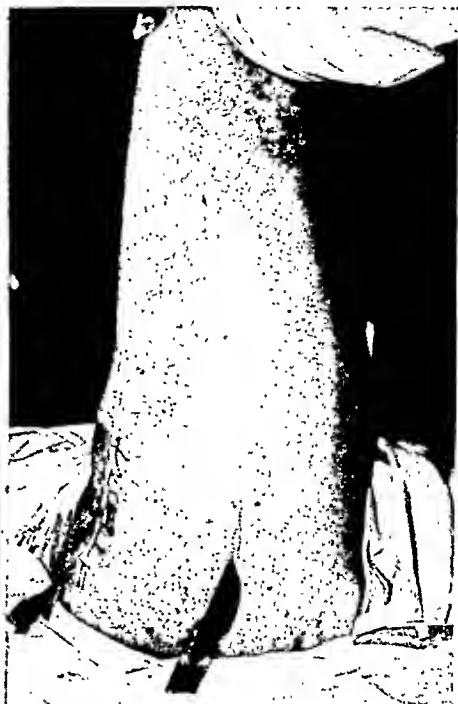


FIG. 4A.—Vertical traction with the lower extremity in 90-90-90 position on the operating table. Wounds, which were débrided in the forward area, are shown. Usually, additional débridement of soft-tissue and bone is required. If wounds do not present a suitable site for drainage, surgical drainage is established in the region of election.

FIG. 4B.—Secondary wound closure, with drainage. Drainage of the fracture site through the posterolateral proximal aspect of the thigh in the region of the gluteal fold.

GROUP I consists of 20 battle casualties with femoral shaft fractures, of which 15 were severely comminuted, four were oblique, and one was transverse. Extensive thigh wounds were present, of which 17 were penetrating, and three were of the perforating type. Initial surgical care was administered in 25.5 hours after injury. Nine days elapsed before surgery in the Base Hospital was begun. Secondary closure of wounds over compound fractures was not condoned during the first months of our work, and secondary surgery consisted of wound débridement, adequate drainage, wound dressing and skeletal traction.

Many of these cases came in with clean wounds, but anemic and seriously ill. The average amount of blood administered per patient was only 1,200 cc. during their entire hospital stay. Wounds were dressed infrequently, but

many became suppurative. Four cases developed general sepsis, three of which had severe osteomyelitis. Drainage of localized abscesses was not an uncommon procedure. Alignment was difficult to maintain when dressings of the wounds were done, since most of the open wounds were over the fracture sites and it was necessary to release the support beneath them while dressings were being changed. At this time vertical traction was not being used as an aid to wound and fracture management. Some of

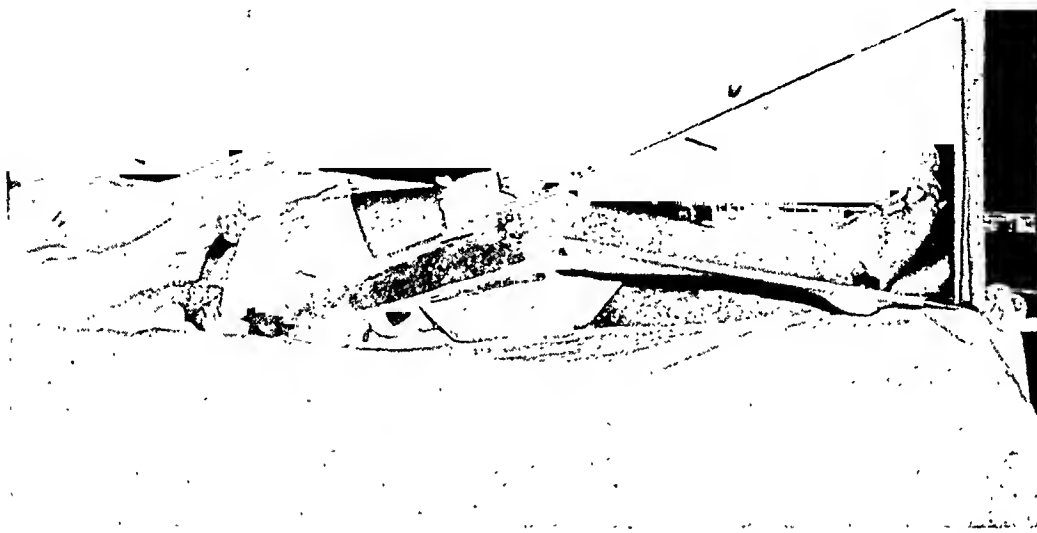


FIG. 5.—The lower extremity is placed in traction with the Thomas splint and Pierson attachment for transportation from the operating room. At the distal ends of the splint and attachment will be noted a wooden bar used to separate the splints.

the patients had fever for many days, the average of which was 17 days for this group.

The unsatisfactory results obtained from the surgical treatment were not surprising in the light of our present conception of wound pathology. In fact, no word picture could paint the local sepsis and systemic debilitation portrayed in many instances. A review of statistical results also fails to reveal the irreparable organic damage that took place, both locally and systemically.

In 17 cases the average time required for wound healing was 8.5 weeks, and in the other three, draining sinuses extending to bone were present at the time of evacuation. The latter three had osteomyelitis, and obtained poor results.

There was roentgenologic evidence of beginning callus in six weeks following injury. Skeletal traction was maintained for nine weeks, average, and clinically firm union was present in that length of time in 17 cases. One osteomyelitis case had a bone deficit and the other two showed evidence of delayed union. There was angulation of the distal femoral fragment in four cases, which resulted in fair anatomic alignment. Another case had an anaerobic bacillus and *hemolytic Streptococcus* infection of the thigh, drained



for ten weeks and ultimately had angulation. Twelve, or 60 per cent, resulted in firm bony union and good anatomic alignment, with healed wounds.

**GROUP II.—*Penicillin and Blood Therapy:*** This group is comprised of 50 battle casualties treated in accordance with the penicillin program. Penicillin became available for the treatment of this type of battle casualty in February, 1944, and, with the assistance of Major Champ Lyons,<sup>6</sup> a program including its use was begun. The fundamental principles advocated were as follows: Twenty-five thousand units of penicillin were administered intramuscu-



FIG. 6



FIG. 7

FIG. 6.—A débrided thigh wound of a patient with a compound fractured femur. Internal fixation with a metal plate and screws was chosen as the procedure of choice, since the patient had a complicating intrathoracic injury which later required chest surgery.

FIG. 7.—Metal-plate and screw fixation of a compound femoral shaft fracture. This was done through an anterolateral incision, with closure of the surgical incision. The wound as shown in Figure 6 was then closed and drainage to the fracture site established.

larly every three hours day and night, for a period of 48 hours before surgery. Laboratory data, consisting of total serum protein, hemoglobin and hematocrit, was obtained by the copper sulfate method.<sup>7</sup> Blood transfusions were given in sufficient quantity to restore the blood volume to normal, based on the estimation that 500 cc. of blood would raise the hematocrit three volumes per cent.

The patient was taken to the operating room for the first dressing, and there complete débridement, if still needed, was done with fracture alignment. Surgical drainage was instituted from the fracture site to the dependent lateral proximal aspect of the thigh with fasciotomy in the region distal to the gluteus maximus and posterior to the tensor fascia femoris muscle. The

drain is best directed in the intermuscular septum between the vastus lateralis and the biceps femoris muscles, thus, avoiding the great vessels and the sciatic nerve. The other wounds were closed and skin grafts were used where necessary. Dead space was reduced to the minimum. Fascial-splitting was done, when indicated, to relieve tension. Usually, 1,000 cc. of blood was given intravenously during surgery and additional transfusions were administered postoperatively, using the hematocrit, hemoglobin and total serum protein reports as a barometer for the amount required. Each patient was maintained on penicillin, with the same intramuscular dosage, until wound healing was progressing satisfactorily, as evidenced by soft-tissue coverage of bone, absence of temperature elevation and return of comfort, with increased appetite.

GROUP II-A.—Nine battle casualties had been previously treated, as outlined in Group I, and all of these had developed suppurating wounds prior to the use of penicillin.

In these nine femurs, five were severely comminuted, three were moderately comminuted, and one was transverse. There were seven cases with penetrating wounds, and two were perforating in type. The time-interval from injury to initial surgery was 18.5 hours, and to Base Hospital surgery eight days. Wound healing required nine weeks in six cases. Three cases were evacuated with open, draining wounds. Callus formation was demonstrated roentgenologically after eight weeks in four cases. Skeletal traction was maintained for an average of eight weeks. Delayed open reduction, and fixation with metal plates, was performed on five cases, of which four obtained good results and one was considered a fair result, because of sepsis complicated by compound fractures of the patella and both bones of the same leg. The results in the remaining four cases were considered poor. In the four poor results, all had wounds which continued to suppurate, three had local bone deficit and the fourth required amputation following evacuation.

Four of these cases were complicated by other wounds. Three had received amputations of the opposite leg resulting from primary trauma. Two had fractures of both bones of the leg; one on the same side and the other on the opposite side. In both cases the tibia was plated.



FIG. 8.—Case 1: Roentgenograms were made while patient was in traction, after osteomyelitis had developed.

## BACTERIOLOGY AND WOUND SEPSIS

All of these 82 compound fractures had contaminated wounds, and 75 per cent showed local evidence of infection. Six, or two-thirds, of those receiving delayed penicillin therapy (Group II-A) had clinical and bacteriologic evidence of aerobic and anaerobic infection. Table I shows the bacteriologic study on five of these cases carried to completion in the penicillin laboratory.

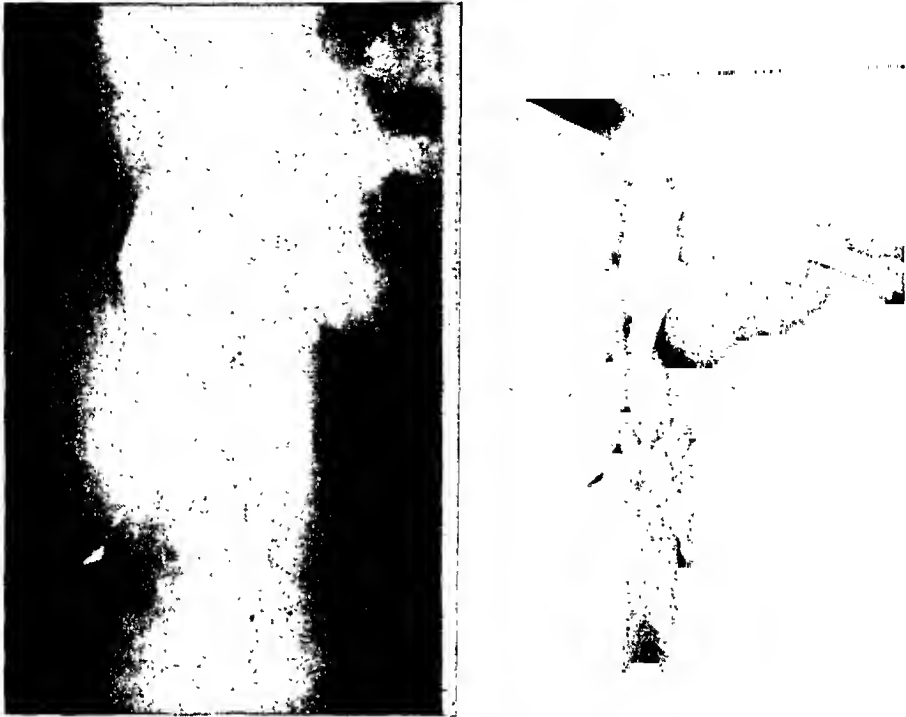


FIG. 9.—Case 3: Early roentgenograms of case before reparative treatment.

The most common organisms encountered from wound cultures were *Clostridia* which were saccharolytic; *Staphylococcus aureus* and streptococci. The isolation and identification of individual species of *Clostridia* was not practicable for the entire group in this hospital. A mixed culture, which produced a stormy fermentation in milk and had morphologic characteristics of the genus *Clostridium*, were identified with saccharolytic *Clostridia*. Many of the wounds showed proteolytic infection, and often penicillin-treated cases had pyocyanic infection.<sup>8</sup>

GROUP II-B.—There were 41 cases treated with penicillin upon admission to this hospital. A few of these had received penicillin a week or more prior to reparative surgery. The mean amount of penicillin administered was 3,100,000 Oxford units per patient. There were 30 severely comminuted, eight moderately comminuted, two oblique, and one transverse fractures. Twenty-eight had penetrating wounds and in 13 the wounds were perforating. Twelve hours had elapsed before initial surgery, and reparative

surgery was begun nine days after injury. Temperature elevation persisted for an average of 13 days. The mean healing time of soft-parts wounded was 4.5 weeks. Callus was evident roentgenologically in 5.5 weeks, and bony union was firm after 11 weeks. Fourteen of these wounds drained for longer than four weeks. Twenty-seven, or approximately two-thirds, healed in two weeks, without suppuration from their wounds or drainage sites.

TABLE I

ORGANISMS IDENTIFIED IN FIVE CASES OF COMPOUND FEMORAL SHAFT FRACTURES IN WHICH BACTERIOLOGIC STUDIES WERE CARRIED TO COMPLETION IN THE PENICILLIN LABORATORY

Organism	No. of Cases in which Present
<i>Clostridium perfringens</i> or <i>Cl. welchii</i> .....	3
<i>Clostridium proteolytic</i> .....	1
<i>Clostridium sporogenes</i> .....	3
<i>Clostridium putrificus</i> .....	1
<i>Clostridium</i> —unidentified.....	2
<i>Anaerobic micrococcus</i> .....	4
<i>Anaerobic streptococcus</i> .....	1
<i>Enteric streptococcus</i> .....	2
<i>Beta hemolytic Streptococcus</i> .....	2
<i>Nonhemolytic Streptococcus</i> .....	2
<i>Hemolytic Staphylococcus aureus</i> .....	3
<i>Pseudomonas pyocyaneus</i> .....	1
<i>Escherichia coli</i> .....	2
<i>Bacillus proteus</i> .....	1
<i>Aerobacter</i> group.....	1

The local complications encountered were bone deficit in two cases, intra-articular fractures of the knee on the affected side in three, major blood vessel laceration in two, secondary hemorrhage in two and local sepsis in six cases. The general complications were five chest injuries, nine cases with other fractures, multiple wounds in 12, intra-abdominal wounds in two, pneumonia in one, posttransfusion anuria in one case and thrombophlebitis of the opposite leg in one patient. No serious complications from penicillin which required cessation of the drug were encountered. Eleven of these fractures were treated with open reduction and metal plate fixation.

There were 38 good results evidenced roentgenologically and by clinical examination for the period of treatment in this Theater of Operations. One femur showed a fair result with side-to-side union and one inch shortening. In two cases satisfactory bony union failed to develop because of bone deficit. The latter were classified as poor results.

GROUP III is comprised of 12 patients all of whom had wound closures, without receiving penicillin. These fractures were comparable to those previously discussed in Group II-B, however, all wounds were nonsuppurative upon admission. Delayed primary closure was done, without drainage, in all except one case which was drained following secondary closure. Seven of this series were severely comminuted. Nine had penetrating wounds and three were perforating in type. Only three cases had temperature elevation and one developed a superficial abscess requiring secondary drainage.

Delayed open reduction, with metal plate fixation, was done on three soldiers in this group and they were given sulfadiazine. The time-interval before initial surgery was 15 hours and before reparative surgery was instituted 6.5 days had elapsed. All wounds healed primarily within four weeks, with the exception of the above mentioned case. Callus formation appeared in six weeks and firm bony union was obtained in ten weeks. These cases only required an average of 1,000 cc. of blood to restore the blood hematocrit and hemoglobin to normal values.



FIG. 10.—Case 3: Late roentgenograms after bony union prior to evacuation.

Among the local complications the following were seen: Delayed union, in which drilling and plating was done after 14 weeks in one case; severance of the popliteal artery, requiring artery and vein ligation followed by repeated novocaine blocks of the lumbar sympathetic ganglia; and fracture of the tibia of the same extremity. There were no general complications.

The patients showed good results in 11 instances, and one was considered only fair due to one inch shortening; however, there was firm bony union.

GROUP IV was composed of 18 simple fractures treated during this period. Five were comminuted, five were oblique and eight were transverse. Satisfactory alignment was not obtained by skeletal traction in four. These were openly reduced and held by metal plates. Callus formation was present roentgenologically in 5.5 weeks, and firm bony union was present at the end of ten weeks.

One patient had a fractured patella on the same side, and five had other

fractures from the initial injury. The only case of bilateral femoral shaft fractures was in this group. Good results were obtained in all cases.

TABLE II

	20 Cases Group I	9 Cases Group II-A	41 Cases Group II-B	12 Cases Group III	18 Cases Group IV
Time-interval to 1st surgery (hrs.).....	25.5	18.5	11	15	10
Time-interval to secondary surgery (days)	9*	8.2**	9***	6.5***	6****
Days of fever.....	17	56	13	11	
Time in traction (weeks).....	9.3	8	11	10	10
Amount of blood administered 300th G.H. (cc.).....	1200	5300	2150	1000	1700§
Amount of penicillin (million units) 300th G.H.....	0	4.32	3.064	0	0
Hematocrit before treatment.....		33%	34%	37%	39%§
Hematocrit after treatment.....		44%	44%	44.3%	43%
Hemoglobin before treatment (Gm.)....	10.4	11	11.7	12	12.7§
Hemoglobin after treatment (Gm.).....	13.2	14.5	14.9	14.5	14.7
Red blood count before treatment (million)	3.2				
Red blood count after treatment (million)	4.6				
Wound healing (weeks).....	8.5*	9†	4.5	4	
Callus (1st x-ray evidence, weeks).....	6	8‡	5.5	6	5.5
Bone healing (weeks).....	9.3*	Unknown	11	10	10

Symbols indicating the type of secondary surgery:

\* Skeletal traction, additional débridement and drainage when indicated.

\*\* Same as Group I. Reparative surgery under the penicillin program was done later.

\*\*\* Reparative surgery.

\*\*\*\* Skeletal traction.

\* 17 cases

† 6 cases

‡ 4 cases

§ 8 cases

#### CASE REPORTS—GROUP I

Case 1.—White, male, age 23. November 11, 1943, 1550 hours, wounded in action by high explosive shell in Italy and received: (1) Wound, severe, distal third of the right thigh involving the knee joint. (2) Fracture, compound, comminuted, distal third of the right femoral shaft.

November 13, 1943: Ether anesthesia, at Evacuation Hospital (24 hours time interval): Débridement of wounds and closure of knee joint capsule. Sulfa-vaselined gauze dressing and Tobruk splint immobilization. Plasma and blood administered.

November 20, 1943: Admitted to General Hospital.

November 21, 1943 (ten days time-interval): Pentothal anesthesia. Kirschner wire was drilled through the area of the tibial tubercle for skeletal traction. Treated in skeletal traction. Wounds not closed. No penicillin administered. Temperature elevation 24 days. Wound did not heal. Callus was present roentgenologically in six weeks. Traction was maintained for 11 weeks.

Original red blood count, 3,430,000. Final count, 4,830,000. Original hemoglobin, 12 Gm. Final hemoglobin, 13.5 Gm. Blood administered, 2,000 cc. Poor results obtained because of wound sepsis and osteomyelitis.

#### GROUP II-A

Case 2.—White, male, age 21. February 22, 1944, 0100 hours, wounded in action by enemy shell fragments in Italy, and received: (1) Wounds, penetrating, left midthigh, severe. (2) Fracture, compound, comminuted, middle third left femoral shaft, severe.

February 22, 1944, 2130 hours (time-interval 20.5 hours), at Evacuation Hospital, pentothal anesthesia. Wounds were débrided and plaster of paris hip spica was applied to the knee of the unaffected side and from the costal margin to the toes on the affected side. Blood plasma was administered.

February 27, 1944. Admitted General Hospital. Good general condition. Temperature elevation 101° F. Plaster of paris encasement intact. Circulation and nerve supply to extremities good. One thousand cubic centimeters of blood administered as transfusion.

February 29, 1944 (time-interval 7 days). Pentothal anesthesia. The encasement was removed in operating room, and there was found to be a great deal of foul drainage from the lateral wound of the thigh which communicated with the fracture. There was edema of the whole thigh. The lateral wound was enlarged for better drainage. Skeletal traction was obtained with a Kirschner wire through the area of the tibial tubercle. No closure of wounds. Twenty-five thousand units of penicillin every three hours begun.

Postoperative treatment consisted of skeletal traction in a Thomas splint and Pierson



FIG. 11

FIG. 12

FIG. 11.—Case 4: Fracture before reparative treatment.

FIG. 12.—Case 4: Fracture immobilized in plaster before evacuation.

attachment, suspended on a Balkan frame. Penicillin amount: 4,200,000 units. Temperature elevation: six days.

April 11, 1944. Pentothal and ether anesthesia. Open reduction with internal fixation with metal plate and screws, because of malposition. Closure of wounds. Wounds healed in eight weeks following injury. Callus was present in five weeks. Treated in traction six weeks before internal fixation.

Wound Cultures: *Staphylococcus hemolytic*, *Streptococcus hemolytic*, *Clostridium welchii*, and *Clostridium proteolytic*.

Original hematocrit, 39 volume per cent. Final hematocrit, 48 volume per cent. Original hemoglobin, 13 Gm. Final hemoglobin, 16 Gm. Amount of blood given was 3,000 cc.

April 29, 1944: Evacuated to the Zone of Interior. Good result. (No roentgenogram available for reproduction.)

#### GROUP II-B

Case 3.—White, male, age 35. June 19, 1944, 2300 hours, wounded in action by shell fragment in Italy and received: (1) Wounds, penetrating, left thigh. (2) Fracture, compound comminuted, middle third, left femoral shaft, severe.

June 20, 1944, 1500 hours (time-interval, 16 hours). At Evacuation Hospital, ether anesthesia. Débridement of wounds and removal of one foreign body. Plaster of paris spica encasement applied to the knee of the unaffected extremity and from the costal margin to the toes of the affected extremity. Penicillin, 25,000 units every three hours for six days postoperatively.

June 27, 1944: Admitted to General Hospital. Condition good on arrival. Plaster encasement intact, circulation and nerve supply to the left foot and toes good.

June 29, 1944: Pentothal anesthesia. Encasement removed, and a wound was found, four inches long, anterolateral aspect proximal fourth of left thigh, which was



FIG. 13.—Case 5: Roentgenograms before reparative surgery. (traced)

nonsuppurative. Kirschner wire was drilled through the area of the tibial tubercle. The wound was débrided and three foreign bodies were removed. Drainage with a Penrose drain through a stab wound posterior and lateral aspect of the proximal fourth of the thigh. Secondary closure of the wound on the anterior and lateral aspect of the thigh.

The patient was treated in traction with a Thomas splint and Pierson attachment suspended on a Balkan frame. Penicillin, 2,200,000 units. Temperature elevation, five days. Wounds healed in 2.5 weeks. Callus formation was present roentgenologically in four weeks. Traction was maintained for 12 weeks. Original hematocrit, 39.5 volume per cent. Final hematocrit, 47 volume per cent. Original hemoglobin, 13.4 Gm. Final hemoglobin, 15.9 Gm. The total amount of blood given was 1,000 cc. Good result was obtained and no complications.

Case 4.—White, male, age 21. June 10, 1944, 1030 hours. Wounded in action in Italy and sustained: (1) Wound, penetrating, right thigh, severe. (2) Fracture, compound comminuted, right femur, midthird.

June 10, 1944, 1630 hours (time-interval, six hours). Ether anesthesia. At Evacuation Hospital. Wounds débrided, removal of foreign bodies and plaster hip spica immobilization extending to knee of unaffected side and from costal margin to toes of affected side.



June 13, 1944. Admitted to General Hospital.

June 15, 1944 (time-interval, five days). Pentothal and ether anesthesia. Encasement removed, two wounds of the right thigh were found. Foreign bodies could not be located. Wounds were débrided and closed. Drainage established. Kirschner wire placed in upper tibia for traction postoperatively. Penicillin, 5,200,000 units. Temperature elevation, 11 days.

June 29, 1944. Open reduction with metal plate and screw fixation. Drainage of thigh. Wounds healed in nine weeks after injury. Bone healing was present 12 weeks

after injury. Original hematocrit, 26.9 volume per cent. Final hematocrit, 41.9 volume per cent. Original hemoglobin, 9.2 Gm. Final hemoglobin, 14.2 Gm. Amount of blood given was 2,000 cc. Local complications were early wound sepsis. Skin graft was done later. General complications were multiple wounds and hepatitis with jaundice. Good results obtained.

Case 5.—White, male, age 20. March 27, 1944, 2245 hours, wounded in action by rifle grenade in Italy and sustained: (1) Wounds, penetrating, both thighs, severe. (2) Fracture, compound comminuted, distal half right femur, involving the knee, severe.

March 28, 1944, 0700 hours (time-interval, eight hours and 45 minutes), at Evacuation Hospital. Débridement of wounds and removal of some foreign bodies. Double spica encasement was applied. Secondary hemorrhage developed and a pack was left in the right thigh to control hemorrhage.

April 4, 1944. Admitted to General Hospital. Plaster spica was intact, and circulation and nerve supply to extremities were good.

FIG. 14.—Case 5: Final roentgenograms after union, and encasement was removed before evacuation.

April 6, 1944 (time-interval, ten days). Pentothal and ether anesthesia. Insertion of Kirschner wire through the area of tibial tubercle. Excision of wounds and removal of one foreign body. Closure of wounds and drainage of fracture site. Treatment in balanced traction with Thomas leg splint and Pierson attachment. Penicillin administered, 2,000,000 units. Temperature elevation, 16 days. Wounds healed in six weeks. Callus was present roentgenologically in six weeks. Traction was maintained for ten weeks, and firm bony union was present in that time. Encasement removed on 14th week. Patient allowed to walk with aid of crutches on the 16th week. Original hematocrit, 40 volume percent. Final hematocrit, 48 volume per cent. Original hemoglobin, 13.5 Gm. Final hemoglobin, 16 Gm. The amount of blood administered was 1,500 cc. The local complication was intra-articular knee fracture. There were no general complications. Good result obtained, with knee motion present.

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### GROUP III

**Case 6.**—White, male, age 23. May 31, 1944, 0830 hours, wounded in action by gunshot in Italy and sustained: (1) Wound, perforating, severe, left thigh, medial and lateral aspects. (2) Fracture, compound, comminuted, upper third of left femur.

June 1, 1944, 0230 hours (time-interval, 18 hours). At Evacuation Hospital. Wounds débrided and vaselined gauze dressings. Plaster spica immobilization.

June 1, 1944. Admitted to General Hospital. Good general condition, with nerve and blood supply present in both extremities. Plaster encasement intact.



FIG. 15



FIG. 16

FIG. 15.—Case 6: Original roentgenograms before reparative surgery.  
FIG. 16.—Case 6: Roentgenograms made after bony union had been established.

June 3, 1944 (time-interval, four days). Pentothal anesthesia, Kirschner wire inserted through the area of the tibial tubercle for skeletal traction. Secondary closure of clean wounds. No drainage of fracture site. No penicillin. No temperature elevation. Wounds healed in three weeks. Callus present roentgenologically in four weeks. Traction was maintained for 11 weeks, and firm bony union was present at that time. Original hematocrit, 39.5 volume per cent. Final hematocrit, 51.9 volume per cent. Original hemoglobin, 15.5 Gm. Final hemoglobin, 17.5 Gm. No blood was given. There were no local or general complications. Result good.

### GROUP IV

**Case 7.**—White, male, age 27, August 22, 1944, accidentally injured in government vehicle in France and sustained: (1) Fracture, simple, comminuted, oblique, severe, middle and distal thirds of the right femur.

August 22, 1944, 1400 hours (time-interval unknown). Plaster spica applied extending from knee on unaffected side to costal margin and toes on affected side.

August 24, 1944. Admitted to General Hospital. Good general condition. Nerve and blood supply intact in both lower extremities.

August 26, 1944 (time-interval, four days). Pentothal and ether anesthesia.



- Kirschner wire was drilled through the supracondylar region of the right femur and the extremity was suspended in 90-90-90 position on the operating table. An anterolateral incision was made, the quadriceps muscle was retracted medially, and through the vastus intermedius the femur was exposed. Osteotomy was done of the intermediate fragment and the fragments were replaced. Internal fixation was obtained with a metal plate and seven screws. The wound was closed in layers with interrupted cotton sutures and silk for the skin.

The patient was treated in a Thomas splint and Pierson attachment for four weeks, after which the extremity was immobilized in a 1.5 plaster spica for evacuation. The incision healed in ten days by primary intention. Callus was present in four weeks. Original hematocrit, 34.1 volume per cent. Final hematocrit, 40.5 volume per cent. Original hemoglobin, 11.8 Gm. Final hemoglobin, 13.6 Gm. Total serum protein was 6.3 and 6.6 volume per cent. Four thousand cubic centimeters of blood was given. Good results obtained.

FIG. 17.—Case 7: Roentgenogram before reparative surgery.

DISCUSSION.—Based on a comparative study of these fracture groups it is our opinion that early adequate forward surgery is of paramount value in the prevention and control of infection. It is essential that patients having sustained injuries, with accompanying shock, should first be stabilized with adequate whole blood and plasma in order that a complete primary wound excision may be performed. The time necessary in preparing the patient to permit proper surgery is of greater value than limiting oneself to a time-interval in which it was previously thought infection could be prevented.

Factors of importance in the primary procedure are as follows: Excision with added surgical exposure necessary to remove devitalized tissue, foreign material and secure hemostasis. This can be done by the use of longitudinal incisions in order to permit closure without tension at a later date. Detached small bone fragments when contaminated promote infection and should be removed. Larger fragments which have an adequate blood supply are essential to healing in supplying a local calcium surplus and should be preserved both to restore continuity and eliminate dead space. Wounds and incisions should be dressed with loosely placed gauze to promote the escape of exudate. Adequate immobilization for transportation is best achieved by the use of a plaster of paris spica encasement extending to the

knee on the unaffected extremity and from the costal margin to the toes on the affected side.

Both from the standpoint of wound healing and fracture alignment, reparative surgery consisting of secondary closure of wounds, with drainage, and skeletal traction has been most satisfactorily instituted in the period from five to ten days after injury. In the cases of Group I, where surgical closure of wounds was not performed, infection often developed by secondary invasion. Tissue closure is best attained by deeply placed interrupted



FIG. 18.—Case 7: Roentgenograms following reduction and internal fixation with metal plate and screws.

vertical mattress sutures of silk in the skin. Proper dependent drainage, as previously described, should be a routine procedure.

Internal fixation with metal plates and screws<sup>9, 10</sup> was done in 23 cases. Nineteen of these were done in compound fractures and four in simple fractures. Open reduction of compound fractures can be safely performed without promoting invasive infection by the use of penicillin. This was done in five cases in Group II-A and 11 cases in Group II-B.

Twenty-two of the cases on which internal fixation was done obtained good results. In the other case there was loosening of the screws because of poor technic requiring removal of the plate, osteotomy and application of a second plate. The ultimate result in this case was satisfactory.

The indications for internal fixation in this series of cases were:

- (1) Oblique unreduced fractures with clean wounds.
- (2) Comminuted fractures with intermediate fragments not likely to be reduced by traction.
- (3) Interposed muscle tissue.

(4) Unreduced fractures, which were not too severely comminuted, and could not be reduced by traction in three weeks.

(5) Complicating additional injuries as intrathoracic, brain, and other fractures or joint injuries of the same extremity where additional surgery was needed during the time traction was essential.

(6) Adequate access to fragments through clean débrided wounds where comminution did not render fixation impossible.

(7) Bone deficit where osteotomy and bone shortening was indicated to promote union.

(8) Delayed union for three months where drilling procedure and rigid fixation was advisable.

(9) Extensive soft-tissue loss which prevented the maintenance of the bony continuity by traction.

Although open reduction with internal fixation was performed in 23 per cent of the compound fractures, excellent alignment was obtained by traction in the most severely comminuted fractures.<sup>11</sup>

Wound healing in 29 cases treated by the open method (Groups I and II-A) was unsatisfactory, with exudation for over two months in 26 of the patients. In the other 53 soldiers with compound femoral fractures (Groups II-B and III) wound healing by primary intention resulted in 38 of the cases. The other 15 cases healed by secondary intention, without systemic complication.

In the nine cases of sepsis treated with delayed penicillin therapy temperature elevation persisted for 56 days after admission to the hospital. In the presence of abscess formation or necrotic tissue penicillin is not a curative agent, nor does it prevent systemic signs of infection. In contrast to this, adequate surgery with early penicillin therapy gave satisfactory wound healing, as stated above.

Although infection in the wound did not materially affect the appearance of callus on roentgenologic examination, delayed union of bone was in direct proportion to the length of time drainage persisted. As far as can be demonstrated from the groups of cases, bone healing was not accelerated by the use of penicillin except in its rôle of controlling invasive infection.

There have been no deaths in this hospital among patients with femoral shaft fractures.

Six out of this series of patients developed anaerobic infection of the thigh, three of which showed clinical and bacteriologic evidence of gas gangrene. We are of the opinion that penicillin was of material benefit in the recovery of these patients.

No amputations were performed on this group of cases, with the exception of the one case after evacuation.

The final classification of these patients was as follows: Good—healed wounds, fracture firmly united in good anatomic alignment, active knee joint motion present through a good range and the patient was expected to obtain

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a normal functional result. Fair—surface coverage of bone even though complete skin coverage was not present, firm bony union with moderate shortening or angulation, expected to have good functional result at a later date. Poor—failure of wound healing, femurs with bone deficit and non-union where further surgery would be required to obtain satisfactory function or osteomyelitis present.

TABLE III  
OUTLINE OF RESULTS

Group	No. of Cases	Good	Fair	Poor
I	20 cases.....	12	5	3
II-A	9 cases.....	4	1	4
II-B	41 cases.....	38	1	2
III	12 cases.....	11	1	
IV	18 cases.....	18		
Total	100 cases.....	83	8	9

### SUMMARY

A comparative study of 100 femoral shaft fractures has been presented. Cases treated without delayed wound closure and without penicillin, are compared with those treated by these methods. Control groups of patients treated with delayed wound closure, and without penicillin, and simple fractures are included. An outline of our surgical management has been given. The indications for employing metal plate fixation in 23 of these cases is outlined. Complications and results for each group of cases while under our care have been discussed.

### CONCLUSIONS

(1) Penicillin and blood are most valuable as aids in the prevention of local and systemic invasion of penicillin-sensitive organisms, but without adequate surgery they alone are not the panacea.

(2) Reparative surgery of the soft tissues consisting of secondary débridement and closure instituted between the fifth and tenth days hastens wound healing in these severe fractures.

(3) The majority of femoral shaft fractures can be realigned by skeletal traction.

(4) Internal fixation of compound as well as simple femoral shaft fractures has been satisfactorily performed where indicated.

(5) The time required for bone healing is in direct proportion to the time wound sepsis persists.

Sincere appreciation and gratitude is extended to the General Hospital staff for the coöperation and aid in the preparation of clinical material and statistics to make this report possible.

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# THORACO-ABDOMINAL INJURIES

## A REPORT OF TWENTY-NINE OPERATED CASES\*

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THORACO-ABDOMINAL injuries have shown a uniformly high mortality rate. Jolly<sup>1</sup> had records on only 26 thoraco-abdominal cases, but of these, 16 died, a 61.5% mortality rate. Michels<sup>2</sup>, in reviewing 83 cases from the Tunisian and Italian Campaigns, found a mortality rate of 48%. Inasmuch, as recent reports of abdominal war wounds<sup>3, 4</sup> have shown a considerable decrease in mortality from the results of World War I, and thoracic injuries in the present war have not been fatal as often as formerly<sup>5, 6</sup> it seems that thoraco-abdominal injuries should, likewise, show a reduction in mortality rate. It is our belief, based on a small group of cases, that this is true. As no surgeon is apt to have a large group of such cases it will be necessary to collect the smaller groups in order to have a series of sufficient size to be statistically significant. This group of cases is, therefore, being reported.

### DEFINITION

There has been some confusion due to inadequate definition. A thoraco-abdominal injury signifies that the missile has entered or traversed both the pleural and peritoneal spaces. This necessitates perforation of the diaphragm. All injuries that involve the chest and abdomen by the same missile are true *thoraco-abdominal injuries*. If separate foreign bodies have entered each of the cavities they are not true thoraco-abdominal lesions as the diaphragm has not been injured. As surgical procedures may differ from those employed in thoraco-abdominal injuries, cases with separate injury to thorax and abdomen are better termed *combined thoracic and abdominal injuries*. All cases here reported had true thoraco-abdominal lesions.

### MATERIAL

In a ten-month period during 1943 and 1944, 31 thoraco-abdominal injuries were seen by a thoracic surgical team of an auxiliary surgical group. During the first month we functioned in a forward evacuation hospital; the remainder of the time with a field hospital. A field hospital, as used in the Italian Campaign<sup>7</sup>, was the most forward medical installation equipped to carry out definitive surgical care. In almost every instance it was set-up adjacent to the divisional clearing station, taking only the most seriously wounded or "nontransportable" cases. As a group, cases treated at a field hospital are more severely wounded than those evacuated to an evacuation hospital.

During the period of this report, except for one month, it was necessary that our team act as a general surgical team and we, therefore, did only a

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\* From the 2nd Auxiliary Surgical Group.



TABLE I

## THORACO-ABDOMINAL INJURIES

Series Number	Unit Number	Age	Agent	Hours, Injury to Operation	Date Operated	Shock Therapy*			Side R or L	Associated Injuries	Approach		Organs Injured	Liver Drainage	Splenectomy	Colostomy	Phrenic Paral.	Chest Drainage	Postoperative Bronchoscopy	Postoperative Course			Remarks		
						Pre-operative	During Operation	24 Hours Post-operatively			Thoraco-Lap.	Lap. & Thoraco-Abdominal								Compli-cations	No. Chest Aspira-tions	Date Evac.		Date Died	
1	82	27	GSW	10	Dec. 6				R	None	X		Liver	O			O	O	O		Jaundice	1	Dec. 19		
2	86	22	HES	4	Dec. 22	250 plasma			R	None	X		Liver	O			O	O	O		None	0	Jan. 1		4 May 44. No symptoms. Back in combat
3	88	20	HES	18	Dec. 21				R	None	Extra Pleural X		Liver	X			O	O	O		None	0	Jan. 1		
4	91	?	HES	?	Dec. 31				L	None	X		Spleen	X			X	X	X		None	0	Jan. 44		Doing well. Feb. 44
5	117	24	GSW	26	Feb. 16	1000 plasma	1000 blood	500 blood	R	None	X		Liver	X			O	X	X		Subphrenic abscess. Bile empyema	10	Mar. 7		28 Apr. 44. OK to go to Z. I.
6	174	22	HES	20	Mar. 7	250 plasma	500 blood	500 blood	R	Right hand, shoulder, arm, eye	X		Liver	X			X	X	X		Jaundice	5	Mar. 16		Letter Aug. 44. OK in Z. I.
7	176	30	HES	5	Mar. 8	250 plasma	1000 blood	1000 blood	L	Left mandible, neck, chest, buttock, femur		X	Jejunum				O	O	X		None	0	Mar. 16		13 May 44. Full duty. Led Sig. Co into Rome
8	180	29	HES	9	Mar. 11	250 plasma	1500 blood	1000 blood	L	Chest, heart pericard. Phr. Ves. Lt. eye, arm, leg and foot	X		Spleen	X			X	X	X		Uremia	0	Mar. 44		Postmortem. Infarct rt. kidney. Transfusion kidney
182	19	MF		7	Mar. 14	500 plasma	1000 blood		R	F.C.C. rt. femur, F.C.C. lt. olecranon, lt. leg	X		Liver	X			X	O	X		Jaundice Pul. embolus Bronchial	0	Apr. 6		Letter June 44. OK going to Z. I
					28	25 gm. albumin																	44		



TABLE I—(Continued)

## THORACO-ABDOMINAL INJURIES

Series Number	Unit Number	Age	Agent	Hours, Injury to Operation	Date Operated	Shock Therapy*			Side R or L	Associated Injuries	Approach			Organs Injured	Liver Drainage	Splenectomy	Colostomy	Phrenic Paralysis	Chest Drainage	Postoperative Bronchoscopy	Postoperative Course			Remarks
						Pre-operative	During Operation	24 Hours Post-operatively			Thoraco-lap.	Lap. Thoraco & Lap. Abdominal	Complications								No. Chest Aspirations	Date Evac.	Date Died	
20	283	30	HES	8	July 44	2000 blood	1000 blood	L	Thoracotomy	X		Colon			X	X	X	X	X	X	None	0		20 July 44
21	290	34	HES	5	July 44	500 plasma 700 autotransf. 1200 blood	500 blood	R	Both chests Rt. arm, buttock		X	Liver	O		O	O	X	None	1	July 44	22			
22	294	24	GSW	11	July 44	1000 plasma 1000 blood	500 blood	L	None		X	Spleen		X	O	O	X	None	0	July 44	29			
23	309	26	HES	7	Sep. 44	500 plasma 1000 blood	1000 blood	L	Amp. rt. hand. Pen WS both legs, arms, buttocks		X	Liver Stomach	X		O	O	X	Lobar pneumonia	1		13		Lobar pneumonia, Both lower and R M lobes	
24	320	30	HES	10	Sep. 44	1500 blood	500 blood	R	None		X	Liver	X		O	X	X	Jaundice	0	Sep. 44	26	Low hematocrit in spite repeated transfusions		
25	322	27	HES	6	Sep. 44	1000 blood	1000 blood	L	None		X	Spleen Stomach Liver Colon	X	X	X	X	O	X	Herniation around colon.	0	Sep. 44	28	26 Oct. 44. Up and walking.	
26	334	19	HES	14	Sep. 44	1000 blood	500 blood	R & L	Pen W shoulder F.C.C. tibia		X	Liver	X		O	O	X	None	0			24th Gen. Hosp.		
27	342	38	HES	16	Oct. 44		1000 blood	L	Perf. W Lt. thigh		X	Pancreas Colon			X	O	O	O	None	1	Oct. 44	12	26 Oct. 44. Doing O.K.	
28	357	19	HES	8	Oct. 44	500 plasma 2500 blood	1000 blood	L	Rt. pneumothorax Pen W face, arms	X		Colon Jejunum	Operation not completed									13	24th Gen. Hosp. Died of shock during operation	
29	358	33	GSW	8	Oct. 44	500 plasma 1000 blood	250 plasma 1000 blood	L	Lt. arm, traumatic thoracotomy. F.C.C. ilium		X	Spleen Colon	X	X	X	O	X	None	1	Oct. 44	21	26 Oct. 44. Doing O.K.	24th Gen. Hosp.	

\* Blood and plasma only

\* Blood and plasma only.  
Data on first four cases incomplete.

proportional number of the thoraco-abdominal cases admitted to the field hospital. Of the 31 cases seen by us, two were not operated upon. One was transferred to another installation. The second, in addition to a left thoraco-abdominal injury, had a right traumatic thoracotomy, traumatic amputation of the right arm and a severe wound of the right thigh. In spite of 3,500 cc. of blood and 500 cc. of plasma a blood pressure was never obtainable and the patient expired five hours after injury, without coming to surgery. This is the only case we saw that died preoperatively. The 29 cases that were operated upon form the basis of this report. Six of the 29 cases ended fatally, a mortality rate of 20.7%.

There were ten cases in which the lesion was on the right side and 18 which were left-sided. One case was bilateral, the same missile having traversed the abdomen and both pleural cavities. In the ten right-sided cases the liver was injured in every instance and was practically the only abdominal organ involved. The right kidney and adrenal were each injured once. The abdominal organs involved in the left-sided cases varied. The spleen was injured in ten of the 18 cases, stomach in 8, colon in 8, liver in 7, jejunum in 4, pancreas in 2 and adrenal in 1. (Table I.) In the one bilateral case the liver was the only abdominal organ involved.

#### AGENT

Fragments of high explosive shells or bombs, because of their irregular, jagged surfaces produce more extensive damage than bullets. In this group of cases, it was found that the missiles in 22 of the thoraco-abdominal injuries were fragments of H.E. shells or bombs and in seven were bullets. A detailed listing of these injuries will be found in Table I.

#### DIAGNOSIS

Sufficient evidence of thoraco-abdominal injury to indicate operative interference is in most instances unmistakable. Thoracic involvement is usually apparent. A wound of entrance or exit that traverses the costal cage must by necessity involve the pleural cavity. Roentgenographic evidence of an intrathoracic foreign body needs no further support. Abdominal injury by a missile whose site of entrance is thoracic may be more difficult to determine. Likewise, many perforating wounds where both entrance and exit are thoracic may leave doubt as to the presence or absence of peritoneal penetration. The course of perforating foreign bodies must be decided on a purely clinical basis, whereas, the path of a penetrating missile is more easily projected from its wound of entrance and its location as determined roentgenographically. Both postero-anterior and lateral projections are necessary.

Physical signs are of little aid in questionable cases. Abdominal pain and rigidity are so often present in thoracic cases that they cannot be relied upon. Peristalsis suggests that injury to a hollow viscus has not occurred, but we have noted it to be present in two of our cases with colonic injuries.

Peristalsis is frequently present when abdominal injury is confined to the spleen or liver. Thus, physical signs are often confirmatory but seldom diagnostic. Various refinements of diagnosis such as pneumothorax or pneumoperitoneum, as reported by Burbank, Samson, Burford and Mesirov<sup>8</sup>, are helpful but not practical except in the base hospital when the acute phase has passed and it is necessary to localize the foreign body only for its removal if indicated.

It is just as necessary to explore any doubtful thoraco-abdominal injury as it is every questionable abdominal penetration. Therefore, unless one is certain that the lesion does not involve the abdomen, exploration is mandatory. Even if no hollow viscus is injured, a damaged spleen may prove fatal or an overlooked perforation of the liver may be the cause of a bile empyema. The only cases that permit any other course are those in which small foreign bodies can be demonstrated to lie within the liver. If such missiles are but one or two millimeters in diameter the chance of their producing sufficient damage to warrant exploration is remote. Any foreign body larger than three millimeters should be considered of sufficient size to demand exact knowledge of the damage it may have produced.

#### APPROACH

No hard and fast rule can be laid down as to the operative approach for all cases. That is, whether it shall be through the chest or through the abdomen, or both. The choice is dependent on three factors: First, whether more extensive damage is expected in the chest or in the abdomen; second, whether the damage can be repaired more easily from above or below; and third, the personal choice of the surgeon, which is dependent upon his training and experience. Thoracic surgeons tend to do more cases from above while abdominal surgeons take the opposite stand and prefer to do as many as possible through the abdomen.

What are the advantages of each approach? The transthoracic method will be discussed first. There are seven factors that need to be mentioned. First, if there is much thoracic as well as abdominal damage, the thoracic part cannot be done from below. Second, certain upper abdominal lesions are more easily handled through the diaphragm. This applies to the spleen, splenic flexure of the colon, upper portion of the stomach (especially if the posterior surface is involved), the dome of the liver, and both kidneys. Third, diaphragmatic repair is best accomplished transthoracically. This is true of both the right and left sides. Small lesions of either side may be closed adequately through the abdomen. But, those over the liver dome and large defects, such as result from tearing the diaphragm from the costal margin, especially posteriorly, must, in most instances, be repaired from above. Fourth, it permits exteriorization of the transverse or splenic flexure of the colon through a subcostal gridiron incision at a greater distance from the operative incision than is possible if a celiotomy has been done. Wound infection is thereby reduced to a minimum. Fifth, postoperative pain is

less severe from a thoracotomy than from a celiotomy. At thoracotomy the two accompanying intercostal nerves are easily exposed and crushed with a hemostat. Having less pain the patient will aerate the lungs more adequately and raise bronchial secretions more completely than if he is experiencing discomfort from an abdominal incision. Sixth, the patient may be carried in a light plane of anesthesia during a thoraco-celiotomy, as abdominal relaxation is not necessary. Seventh, although it may not be apparent preoperatively, considerable damage to the intrathoracic organs may be present. This will not be determined and its repair, therefore, not accomplished if the exposure is an abdominal one.

The factors favoring an abdominal approach are two. It is indicated to repair lesions of the lower ileum, cecum, ascending, lower descending, sigmoid and hepatic flexure of the colon. Many of these organs cannot be adequately exposed transdiaphragmatically. In such instances celiotomy is mandatory. Second, should the thoracic disturbance be minimal and operative therapy not indicated, (such as a small hemothorax or minor perforation of the lung) an abdominal exploration prevents entering another serous cavity.

It is apparent, therefore, that certain lesions are best done from above and certain others from below. Inasmuch, as most of the abdominal damage will be found in the upper abdomen it is advisable to do all questionable cases from above. Also, if it appears that there has been appreciable damage in the thorax the lesion is best approached through the chest. Should such exploration reveal abdominal lesions that cannot be adequately exposed one should have no hesitancy in doing both a thoracotomy and a celiotomy. If the thoracic physiology is restored by thoracotomy the patient is in better condition to withstand a celiotomy. It is the practice of some surgeons to handle such a problem by extending the thoracic incision through the costal cartilages and on to the abdomen to gain the necessary exposure. We do not hold with this opinion, as dividing the costal cage makes for instability of the chest and enhances the chance of postoperative pulmonary complications. It takes no longer to do both a thoracotomy and a celiotomy, which is the method we prefer. Finally, one must take account of the experience and qualifications of the individual surgeon. We do not propose that the performance of a thoracotomy is a difficult procedure nor that the postoperative management of patients subjected to intrathoracic operations is difficult. However, the general surgeon whose experience in modern thoracic surgery has been limited, does not fully appreciate the importance of securing air-tight closure and stability of the thoracic cage, complete and rapid reexpansion of the injured lung, and the maintenance of a clear tracheobronchial passage during the postoperative period. If the surgeon does not feel confident that he can accomplish these objectives it is safer for him to utilize the abdominal approach. The corollary of this may also be true in that the thoracic surgeon with limited experience in abdominal surgery may not fully appreciate all the problems associated with the man-

agement of abdominal lesions. We believe that most thoracic surgeons have had a sufficiently broad general surgical foundation to repair adequately the abdominal trauma and to care for the patient postoperatively.

#### OPERATIVE TREATMENT

The principles of the operative treatment of thoracic and abdominal lesions have been discussed ably by many authors. We would like, however, to briefly present a few points in regard to thoracoceliotomies that deserve reiteration or added comment.

*Anesthesia.*—The importance of a skillful anesthetist has been brought out previously.<sup>5</sup> A thoracoceliotomy is to be avoided in the absence of such. A good anesthetist can sustain an inexperienced surgeon better than a brilliant surgeon can support an inexperienced anesthetist. Endotracheal gas-oxygen-ether by the closed system has been our choice for all war injuries in which it is contemplated to open either the thoracic or abdominal cavities<sup>9</sup>.

*Incision.*—If the approach is to be thoracic the incision must be placed so as to give maximum exposure. We have found the region of the eighth to tenth ribs most advantageous. If the incision is below the level of the tenth rib the entire diaphragm cannot be inspected. Should the foreign body appear to have injured the posterior or lateral portions of the diaphragm, we have used the tenth rib; for central portions of the diaphragm the ninth rib; for anterior or medial diaphragmatic segments, the eighth rib. The incision is made through the débrided wound if the wound is in the area of election, otherwise, a separate incision is made. If the former, meticulous wound excision is essential to prevent infection. Adequate exposure is of prime importance. It may be obtained either by rib resection or by intercostal incision. In one case (Case 3) we were able to dissect the pleura from the costophrenic sinus and pack a liver lesion extrapleurally and extraperitoneally.

*Diaphragmatic Repair.*—The diaphragm can be repaired by many different methods. Inasmuch as there have been reports of bile empyemata<sup>4</sup> on the right side and diaphragmatic herniae on the left, it is necessary to repair the diaphragmatic defect as securely as possible. In our hands, a two-layer closure has been found the most satisfactory. The first layer of sutures is so placed as to overlap the two diaphragmatic portions by an imbricating suture. The overlapped edge of the diaphragm is then sutured down to the underneath segment. If the diaphragm is overlapped two to three centimeters a very strong closure is obtained. All sutures are of cotton or silk and all are placed interruptedly. This type of repair is seldom possible through an abdominal approach.

In most instances it has been our practice to pinch the phrenic nerve at the lower edge of the pericardium. This paralyzes the hemidiaphragm for a period of four to six weeks and, thereby, enhances adequate healing. Although this procedure has been thought by some<sup>10</sup> to be unnecessary, it seems as logical to us as to splint an extensive wound of an extremity without fracture,

which is admittedly an advisable procedure. We have not noted any untoward postoperative pulmonary complications attributable to the diaphragmatic paralysis.

*Hepatic Injuries.*—Any liver lesion that warrants exploration should be packed or drained. The pack or drain is brought out subcostally in such a manner as to provide dependent drainage. Certain innocent-appearing liver perforations may have damaged the larger bile radicals and such cases subsequently develop bile peritonitis if drainage has not been provided.

*Chest Closure.*—Closure of the chest and lung reëxpansion are of basic importance in performing a transthoracic procedure. This has been previously emphasized by us,<sup>5</sup> but will be summarized here. All blood in the thoracic cavity is aspirated and the hemithorax then flushed with 2,000 cc. of saline. This permits adequate inspection and repair of any pulmonary lesion. Furthermore, the incidence of organizing fibrothorax, which has been a problem to those in the base sections,<sup>11</sup> is probably diminished. Securing apposition of the lung and thoracic cage is an important part of the operation. We have found that it is most easily obtained in the following manner. As the pleural closure is started, the anesthetist gently increases the intrabronchial pressure to plus 5 cm. to 10 cm. of water. A No. 22 F. catheter, with at least two holes, is inserted into the chest through the pleural sutures and so placed as to lie in the uppermost portion of the chest. The suction machine is then attached to the catheter after an air vent has been made near the proximal end of the catheter. This prevents too much suction, which might damage the lung but does provide encouragement toward expansion. The pleural closure is then completed. (We often find it helpful in closing the posterior aspect of the pleural incision to pull over it the paraspinalis muscles, thus reënforsing the pleural suture line). When the pleural repair is completed the intrabronchial pressure is increased by the anesthetist to 15 cm. to 20 cm. of water. At the same time the surgeon carefully increases the suction on the catheter with his finger. A suture is placed around the catheter by the assistant and the catheter slowly withdrawn and the suture tied to prevent any ingress of air through the defect.

*Chest Drainage.*—If it is decided to drain the chest with underwater drainage such extensive precautions to obtain lung expansion are not necessary, as the air will be expelled gradually. In our experience a single posterior catheter does not always guarantee such a state of affairs. Two catheters, one posteriorly and one anteriorly in the second interspace will give better results than a single one. When drainage is not employed the patient must be examined frequently and any detectable accumulation of air and/or fluid aspirated. We have been pleasantly surprised by the number of times we have found it unnecessary to aspirate the chest following closure without drainage. In Table I, it will be noted that the average number of chest aspirations in the drained cases was 2.3 while in the undrained cases it was 0.8.

We are aware that the principle of drainage of the pleural space in all thoracic war injuries has been accepted and widely practiced. However,



difficulties encountered by us in maintaining satisfactory drainage in forward medical installations during rush periods of activity led us to revert to our former practice of not draining, except in unusual circumstances. The objective is complete, early lung expansion. We have more often achieved this result without drainage than when drainage was employed.

#### POSTOPERATIVE CARE

It is not necessary to go into the postoperative care of the abdominal patient. Three important points in regard to the thoracic phase of thoraco-abdominal injuries should be mentioned. The first was noted above, that is, removal of all air and fluid in the chest so as to attain complete lung expansion. A good rule to follow in this regard is to aspirate daily as long as at least 100 cc. of air or fluid are obtained. If less than this amount, aspirate every other day until the chest is dry and the lung expanded.

The second problem has to do with pulmonary secretions. It is of utmost importance that the tracheobronchial tree be cleared of excessive secretions as often as indicated. In many, the trachea and bronchi should be aspirated bronchoscopically at the completion of the operation. As all such cases are done with endotracheal anesthesia, the anesthetist is experienced in exposing the larynx. If he is not already trained in bronchoscopic aspiration it can be learned quickly with a few instructions. With such an anesthetist in attendance it is convenient for him to bronchoscope the patient as soon as the intratracheal tube has been removed. This can often be done as the closure of the incision is being completed.

It is our practice to carry out this procedure on all patients who have shown evidence of blood or excessive bronchial secretions either preoperatively or during operation. In this series of 29 cases postoperative bronchoscopy was deemed necessary in 23 (Table I).

After the patient returns to the ward he should be carefully observed for signs of excessive bronchial material. This is evidenced either by a rattling type of respiration or by frequent ineffectual coughs. Whenever such a state exists it can be combated by one of two methods: First, supporting the patient's chest so as to make coughing more effectual. (This should be done periodically by the nurse in all cases.) Second, should coughing still not clear the air-way, the secretions must be removed mechanically. The simplest and easiest method is by introducing a catheter into the trachea and aspirating the material. The method of introduction of the catheter has been described by Haight<sup>12</sup> and easily mastered. In the more severe cases, or for those in which the catheter is not sufficient, bronchoscopy is indicated. This can be performed on the ward, under local anesthesia, without moving the patient from his bed. The stimulation to cough by the presence of either the catheter or bronchoscopic aspirating tip in the trachea is a powerful one and the patient is thereby forced to cough and thus loosen other material beyond the reach of the aspirator. The importance of this phase of postoperative treatment is such that we believe all members of any thoracic surgical team,

surgeon, assistant surgeon and anesthetist, should be competent bronchoscopists in order that the benefits of bronchoscopy will be always available.

The third factor is control of postoperative pain. This is usually not severe if the operation has been a thoracoceliotomy and the accompanying intercostal nerves have been paralyzed. If discomfort is pronounced it should be relieved to encourage full expansion of the chest and permit forceful but nonpainful coughing. Such pain is much better controlled at its source by paravertebral intercostal nerve block than by resorting to morphine or other depressant drugs. A nerve block can readily be done on the ward. It will be found to be far more effective and the relief much more prolonged than the relief obtained from morphine. Although it seldom is necessary to repeat the nerve block, it may be repeated without harmful effects as often as necessary.

### RESULTS

In discussing results in war surgery several factors of great importance have to be considered. The time-lag from injury to operation, severity of concomitant wounds, and in abdominal injuries, the abdominal viscera involved are the more important associated factors. The latter is greatly influenced in thoraco-abdominal cases by the side of the injury.

It is regretted that a follow-up study of our cases has not been possible. Reports that have been received are noted in Table I. The total mortality after a complete follow-up may, therefore, be somewhat higher than here indicated. Twenty-nine thoraco-abdominal injuries have been operated upon by us with six known fatalities, a mortality rate of 20.7 per cent.

*Fatal Cases.*—Case 8 died on the third postoperative day, with all the signs of uremia (oliguria had been present from the first). At postmortem, a large infarct of the left kidney was found, although the kidney was not injured by the missile. A report of the microscopic examination has not been received. Case 12 died during bronchoscopy at the completion of the operation. It is our belief that he died of a "vago-vagal reflex." It is now our practice to give all patients atropine  $\frac{1}{100}$  gr. intravenously 10 to 15 minutes before bronchoscopy. This reflex has not been observed to occur if the patient is either deeply anesthetized or fully conscious. It has always occurred in our experience when the patient was at the "in between" stage while coming out of anesthesia. The third fatality (Case 17), occurred on the third postoperative day, due to uremia. Case 19 died of strangulation on the ward three hours postoperatively. Postmortem examination revealed no other cause of death. Case 23 died on the second postoperative day of a fulminating lobar pneumonia involving the right lower, right middle and left lower lobes. Grossly, the process on the right side was older than that on the left. (Operation was through the left chest.) The sixth fatality (Case 28), occurred on the operating table. The patient had a left thoraco-abdominal injury but an associated right pneumothorax presumed to be due to a "blast" injury. Even after aspiration of both hemithoraces preoperatively, tracheal aspiration, nerve block

and 2,500 cc. of blood and 500 cc. of plasma the blood pressure could not be elevated above 85 mm. systolic. Inasmuch as fecal material was pouring out the thoracic wound it was believed that the low blood pressure was due to gross contamination and operation was undertaken even though a fatal issue was contemplated. A catheter attached to a water-seal was introduced into the right chest in case it continued to leak air. Left thoracoceliotomy was done. The spleen was found injured and, therefore, removed. The jejunum was transected and devitalized for a distance of 15 inches. The splenic flexure of the colon was transected and lacerated, necessitating resection of ten inches. Although another 1,000 cc. of blood was given during operation, his condition continued to grow worse and he expired before the operation was completed.

The deaths of Cases 8 and 17 are attributed to posttraumatic uremia, a comparatively frequent cause of death in the severely wounded. Case 23 died of lobar pneumonia and Case 28 of shock due to gross contamination of the abdominal and pleural cavities by fecal material. It is of interest to note that the time-lag from injury to operation was eight hours on the average for the fatal cases and 11.4 hours for the nonfatal group. This does not mean that the time-lag is unimportant but probably indicates that many of the more severely wounded die before reaching any medical installation. All the cases with severe concomitant wounds survived, which is no doubt due to the preoperative preparation plus skillful anesthesia with adequate oxygenation during a long operation.

*Colon Injuries.*—Three of the eight cases that had colon injuries succumbed (37.5 per cent). In only one, however (Case 28), can it be called the primary cause of death. This group is too small to be of statistical importance but it compares favorably with mortality rates for colon injuries reported by Jarvis,<sup>4</sup> 49 per cent of 107, Hurt,<sup>3</sup> 47.2 per cent of 286, and Ogilvie,<sup>13</sup> 58 per cent of 107 cases.

*Side of Injury.*—It has been recognized that left-sided thoraco-abdominal lesions are apt to be more hazardous than right-sided ones, as the liver is often the only abdominal organ involved when the missile stays in the right upper quadrant. Our only fatality in right-sided cases was the one (Case 19) that died of strangulation. Five of the 18 left-sided ones died. Thus, if the one bilateral case is included in the right-sided group (the liver was the only abdominal organ injured) the mortality for right-sided lesions is 9.1 per cent while the rate for the 18 left-sided cases is 27.1 per cent.

Shefts, *et al.*,<sup>14</sup> another thoracic surgical team, are to report shortly on their series of thoraco-abdominal lesions. Most of their cases were done in an evacuation hospital and the right-sided lesions predominate. At the present time,<sup>6</sup> they have done 47 cases, of which 30 were on the right and 14 on the left, and three were bilateral. Eight cases died, a mortality of 17.0 per cent. The mortality rate for each side is not available at present.

*Number of Abdominal Organs Injured.*—Sanger<sup>15</sup> recently reported on 100 thoraco-abdominal cases operated upon in an evacuation hospital. He pointed out the marked difference in mortality for those cases with only one

abdominal viscus injured (probably mostly right-sided cases) as compared with those having two or more organs involved. He found that of the 51 cases with one organ seven died, or 13.7 per cent, while 20 of the 35 with two or more organs ended fatally, a rate of 57.1 per cent. Our series shows one death in 15, or 6.6 per cent, for one abdominal viscus, and five deaths in 14 for two or more abdominal organs, a rate of 35.7 per cent.

COMMENT.—Although it is ill-advised to draw conclusions from such a small series of cases, and at such an early date, if we are to learn about war surgery and put the lessons to use in time to save soldiers' lives we must arrive at working impressions as early as possible. Recent published reports of other series of thoraco-abdominal injuries are not available to us. However, it seems justifiable on the basis of 76 cases (our own and Shefts,<sup>6</sup> both thoracic surgical teams of the same auxiliary surgical group), to indicate what we believe can be learned from this series.

1. An expert physician anesthetist is invaluable for the proper function of a thoracic surgical team functioning in a first-priority surgical hospital and, as far as possible, thoraco-abdominal wounds should be cared for by a team whose anesthetist is experienced in the administration of intratracheal anesthesia.

2. Fatalities occur but rarely on the operating table. The complications and difficulties encountered postoperatively, as observed in our own cases and in those seen in consultation for other surgeons, have, in the vast majority, been pulmonary in character. They often tax the resourcefulness and ingenuity of one experienced in thoracic surgery. Every thoraco-abdominal case may need either tracheal aspiration by a catheter or bronchoscopy during some stage of his postoperative course. General surgeons or their anesthetists, as a rule, are unfamiliar with, or do not carry out, these measures sufficiently often.

3. Pulmonary reëxpansion after a thoracic operation is of utmost importance. Simply draining the pleura with an underwater-seal will not guarantee reëxpansion. The objective of complete lung expansion must be pursued vigorously until the end is attained, whether or not the chest has been drained at operation.

4. It has been our impression, borne out by this series, that the prolongation of the time-interval by two to three hours from injury to operation is not as significant in respect to mortality as are the factors of proper anesthesia and postoperative care. If it is necessary to transport such patients to hospitals staffed with personnel qualified to accomplish these requirements this increase in time-interval will be well compensated by a decreased mortality rate.

#### SUMMARY

Thirty-one thoraco-abdominal injuries treated by a thoracic surgical team of an auxiliary surgical group during the Italian Campaign have been presented.

Of the 29 operated cases, six died. The causes of death have been discussed.

The approach, whether transthoracic, abdominal, or both, has been presented with the various advantages and indications for each.

Certain steps in the operative care, including the method of diaphragmatic closure, have been described.

The importance of complete lung expansion and removal of excessive pulmonary secretions postoperatively has been emphasized. It is advisable that at least one, and preferably all members of any surgical team caring for thoraco-abdominal injuries should be competent bronchoscopists.

It is suggested that medical installations caring for such patients be staffed by well-qualified anesthetists and surgeons with thoracic surgical experience.

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# ANESTHESIA FOR MEN WOUNDED IN BATTLE

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ADVANCES IN SURGERY in the 30 years since the start of World War I have in a number of cases been made possible by progress in the field of anesthesia. This progress has required acceptance of the view that surgery acceptable by the standards of 1945, cannot be achieved if anesthesia equipment and technics and personnel are limited to those of 1914. An attempt will be made here to sift out the anesthesia procedures found to be practicable under the circumstances of warfare and necessary for the best military surgery, surgery unrestricted by anesthesia.

Intravenous anesthesia, sodium pentothal, has had its first significant trial in military medicine in the present conflict. The technic is admirably suited to the needs of warfare; but the extravagant statements made for and against it, above all its newness in military medicine, all suggest the desirability of a fuller discussion of this agent, than of the others employed. This has been undertaken.

This report is based upon experience in the Mediterranean Theater of Operations. It has been made possible by the wholehearted coöperation of the anesthetists of the Theater.

## ANESTHESIA AGENTS AND TECHNICS IN THE COMBAT ZONE

### *Some Limiting Factors*

A number of factors here are of enough importance to limit considerably one's freedom of choice. *Mobility of equipment and availability of supplies:* Even the 400 bed evacuation hospitals on occasion have to dispose of their patients, tear down their equipment, move many miles over difficult, congested roads, set-up and be ready to receive patients about 24 hours after the first notification of the move. The rough handling inevitable if such speed is to be obtained means that complicated gas machines often become so battered that they leak and lose their serviceability. The premium to be placed on simple durable equipment is evident. The problems arising from interruption of supply and constantly changing supply routes soon convinces the most enthusiastic anesthetist that he had better get along, if need be, with a few agents that can be transported by hand\* or administered by improvised equip-

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\* It must be recognized that for some types of surgery a satisfactory survival rate cannot be obtained unless a closed anesthesia apparatus is provided which will permit the administration of positive pressure anesthesia, notably in open thoracic surgery. As a result of the coöperation of the Surgeon-General, 50 of the small transportable anesthesia outfits described by Beecher (an easily transportable apparatus for anesthesia with or without compressed oxygen, War Medicine 2, 602, 1942) were obtained and tried out. The

ment. These are adequate reasons for the frequent limitation of anesthesia agents in the forward zone to ether, sodium pentothal and procaine hydrochloride. *Problems of personnel* will be discussed in more detail later, but it can be mentioned, in passing, here that they, too, offer some arguments for this simplification. Observe, for example, the section on personnel, where it is pointed out that a third of the Theater's physician "specialists" in anesthesia had had only three months or less special training.

While it was necessary to press into service a good many men who had had little special preparation in anesthesia, these men have rendered a superb service in which earnest application to the job to be done has gone far to override limited training in the field.

#### PREPARATION OF THE PATIENTS FOR SURGERY

This is an important matter and has been discussed in detail elsewhere.<sup>1</sup> It is customary in a report of this kind to discuss preanesthetic medication. This has been done so frequently by various writers in the past little more needs to be said on the subject. In the opinion of the writer, based upon first-hand experience on the Cassino front and at the Anzio Beachhead, the seriously wounded need very little preanesthetic medication. The use of morphine had better in most cases be avoided, except when needed for the relief of severe pain. As pointed out elsewhere,<sup>2</sup> when the peripheral circulation is poor as in chilled or shocked patients, morphine previously administered may or may not have been absorbed from subcutaneous deposits. With resuscitation and later with the peripheral vasodilation associated with ether anesthesia, the injections of morphine may be rapidly taken up into the blood and poisoning appear. In any case, the use of morphine is not necessary as a routine in these patients. Atropin is important to cut down the flow of mucus under ether and also as described in the section on pentothal anesthesia.

Intratracheal intubation under general anesthesia is desirable for intracranial, maxillofacial, thoracic (pleural involvement) and abdominal surgery and in other cases where the position of the patient makes it difficult to maintain a good air-way, and finally when the operation promises to exceed an hour or so.

While preparation of badly wounded patients for surgery should include check on the availability of a bronchoscope, the *routine* use of this, even in open thoracic cases, is undesirable for the following reasons: The air-way

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manufacture of these is relatively simple and rapid and the use of critical materials rests at a minimum. Light (14 lbs. boxed), simple, and durable, having few parts there is little to get out of order and few opportunities for leaks. The apparatus takes up little space in crowded operating tents and is easily transportable by hand. Its safe use is much more easily and quickly mastered by inexperienced anesthetists than is true of the more complex apparatus provided. Use of the apparatus in the combat zone established that it was adequate for the most complicated types of thoracic surgery, as well as for any inhalation anesthesia. The apparatus is also readily available for oxygen therapy or artificial respiration.

# ANESTHESIA FOR WOUNDED MEN

should, if necessary, be kept clean by means of frequent aspiration of the trachea through a catheter. Use of the bronchoscope at the end of operation involves one of three things, all undesirable: If the bronchoscope is to be introduced at this time either the anesthesia must be maintained at a deep level for an undesirably long time, or it must be deepened with possible harm to the patient at the end of a trying operation when the condition of the patient may be poor, or topical anesthesia must be used. In this case, if the patient vomits on recovery from the general anesthesia he is almost certain to aspirate vomitus through his locally anesthetized air-way.

TABLE I

SAMPLE DISTRIBUTION OF ANESTHETICS FOUND IN FORWARD AND REAR AREAS

(Based on Tunisian and Sicilian Campaigns, from June to September, 1943. Compare with Table II)

Area	Percentages are Based upon the Following Number of Cases	Inhalation (Ether Chiefly)	Intravenous (Sodium Pentothal)	Spinal (Procaine HCl Chiefly)	Local (Procaine HCl Chiefly)
Forward:	1,104	18.0%	53.2%	19.8%	9.0%
Field Hospitals					
Evacuation Hospitals					
Rear:	5,279	14.3%	27.7%	38.2%	19.7%
Station Hospitals					
General Hospitals					

TABLE II

SAMPLE DISTRIBUTION OF ANESTHETICS CURRENTLY FOUND IN FORWARD AND REAR AREAS

(Collected January through August, 1944, for comparison with Table I)

Area	Percentages are Based upon this Number of Cases	Inhalation				Intra-venous (Sodium Pentothal)	Spinal (Procaine HCl Chiefly)	Local Regional		Avertin Basal	Combined†
		Open Ether	Closed Ether*	Nitrous Oxide	Chloroform			All 3	Chiefly		
Forward:	10,734	11.6%	8.7%				3.0%	13.4%	0.7%		
Field Hospitals		(20.3%)				62.6%‡					
Evacuation Hospitals											
Rear:	9,180	2.6%	5.9%	0.2%	0.1%	48.1%	15.0%	20.4%	2.2%	0.1%	5.4%
Station Hospitals		(8.8%)									
General Hospitals											

\* Includes those with nitrous oxide induction.

† Agents are listed as "combined" when two or more agents are both used for prolonged anesthesia. This classification does not include brief induction of one agent by another, nor "basal avertin."

‡ In the forward area, the use of sodium pentothal is almost entirely limited to the evacuation hospitals. It is rarely used in the field hospitals where the nontransportable type of patient is cared for. It provides for practically all of the anesthesia for major cases in field hospitals.

## INHALATION ANESTHESIA

*Ethyl chloride* or *chloroform* have been used so infrequently in this Theater (for incidence of use, see Tables II and III) as to merit little comment. It has been suggested that chloroform in small ampoules be used by



nonmedical personnel to overcome wounded manic individuals in burning tanks so that they might more easily be removed through the narrow escape hatch. So far as the writer knows the agent has not been used for this purpose in this Theater. With the other agents now available it is difficult to find any legitimate anesthetic use for chloroform, except in the rare circumstances where sodium pentothal, nitrous oxide, or local procaine are not adequate and when use of a noninflammable agent is imperative. The effects of the agent are such that there can be even less excuse for using it in men wounded in battle than in nontraumatic civilian practice where the agent has been

TABLE III

## SAMPLE DISTRIBUTION OF ANESTHETICS FOUND IN FORWARD AND REAR AREAS

*These data overlap those of Tables I and II as far as time of collection goes, and show transition between early and current (Table II) practices. They are included here because they are based upon a larger volume of material than are Tables I and II*

Area	Percentages are Based upon this Number of Cases	Inhalation			Nitrous Oxide	Ethyl Chl.	Chloro- form	Intra- venous (Sodium Pentothal)	Spinal	Local All 3 Procaine HCl	Regional Chiefly HCl	Avertin Basal	Com- bined†
		Open Ether	Closed Ether*										
Forward: Field Hospitals Evacuation Hospitals	19,464	9.7%	7.2%	0.2%	0.02%			62.3%	6.0%	13.0%	1.3%	0	0.4%
			(17.1%)										
Rear: Station Hospitals General Hospitals	21,598	2.9%	6.5%	0.7%	0.2%	0.04%	38.3%	23.3%	19.8%	4.6%	0.1%	3.7%	
			(10.3%)										

\* Includes those with nitrous oxide induction.

† Agents are listed as "combined" when two or more agents are both used for prolonged anesthesia. This does not include brief induction of one agent by another, nor "basal avertin".

adequately discredited for many years. Ethyl chloride, because of its easy transportability and rapid transient action, has had a little use as an inducing agent or for use to dull the pain of brief procedures.

*Cyclopropane* or *ethylene* have not been issued to the American Army in this Theater.

*Nitrous oxide*, when available, is useful for minor surgical procedures (painful changes of dressings), supplement of other forms of anesthesia (notably 50 per cent nitrous oxide with 50 per cent oxygen to add to the effect of sodium pentothal) and induction of ether anesthesia. While nitrous oxide is useful its value by no means ranks with that of the important three: ether, sodium pentothal, and procaine hydrochloride. The straight induction of ether is remarkably easy and apparently not unpleasant in the badly wounded, whether by open-drop or better by closed machine with oxygen. The use of nitrous oxide is convenient when available but is not indispensable.

*Ether* is the choice in the seriously wounded. This is true whether the seriousness of the wounds depends upon widespread tissue destruction, pene-

tration of important body cavities or is due to severe hemorrhage through otherwise trivial wounds. When surgery must be undertaken in patients in shock or when shock is impending, it has been clearly demonstrated that ether is the best tolerated of any of the available agents. Ether is now so widely recognized as the most desirable agent for use in the seriously wounded, its corresponding merit is evident for patients who are less badly off. It provides for practically all of the anesthesia for major cases in field hospitals.

Early practice in the Theater was to use ether too little. The 2 per cent increase (cf. Tables I and II) in the forward hospitals in the use of ether over the past year is of doubtful significance. Not adequately shown by the type of table presented is the increased use of ether in the numerically relatively small but surgically important group that includes wounds of the abdomen, the thorax and compound fractures of the femur.

#### INTRAVENOUS ANESTHESIA

Perhaps the best way to approach the problem will be deliberately to reverse the usual order of discussion and present first some of the end-results\* of the use of this agent as found in the survey of September, 1943, as contrasted with the survey made a year later (September, 1944), for this approach will make clear the reasons for some of the decisions made regarding this anesthetic agent.

*Background.*—At the time of the first survey, September, 1943, deaths from sodium pentothal were so common, not only as shown in the sample data in Table VI but throughout the Theater, both before and after this survey, that the question was raised of abandoning the agent. Moreover, experience here was then in line with reports arising from use of the agent at Pearl Harbor. But examination of the deaths that had occurred here indicated that two correctable factors were present: (a) Its frequent use by completely inexperienced individuals. ("You need only to be able to hit a vein to be an anesthetist these days"); and (b) its use in cases where actually contraindicated. Because of the unquestionable advantages of the agent in warfare, the decision was made to continue its use, at the same time taking measures to correct (a) and (b).

The simplicity with which pentothal anesthesia can be made available, particularly the compactness and the simplicity of the necessary equipment, the ease with which smooth induction can be produced even by the inexperienced, the usual prompt awakening of the patient, the infrequency of unpleasant after effects, the number of cases an inexperienced man can "get

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\* In Tables V and VI, and occasionally here in the text, the phrase "death rate" has been used for brevity. This has been placed in quotation marks to give it a special significance. Obviously one cannot speak of rate in a precise mathematical sense when, as in Table VI, two deaths occurred in 11,000 cases; yet a year previously, in a quarter as many cases, three times as many deaths had occurred. This 12-fold difference indicates that a real change for the better had taken place. So the data will be set down in this way to suggest order of magnitude, nothing more.

away with" even though his actual death rate may be unreasonably high in comparison with what it should be—all of these factors have tended to outweigh the fact that pentothal is a powerful tool, that overdosage is not always easy to overcome, that sodium pentothal's use is incompatible with certain types of injury, and that its fatal dose varies extremely widely from one patient to another.

TABLE IV  
DISTRIBUTION OF SURGERY IN THE TWO AREAS

Area	Percentages are Based upon this Number of Cases	Ex-tremities	Chief Region Requiring Surgery						
			Abdomen	Inguinal Hernia	Thorax	Central Nervous System	Misc. (Major)	Misc. (Minor)	Ear, Nose, Throat
Forward:	9,199	28.0%	7.0%	0.5%	3.1%	1.7%	2.8%	56.3%	0.6%
Field Hospitals									
Evacuation Hospitals									
Rear:	11,261	13.4%	6.5%	1.6%	0.8%	1.4%	2.9%	71.4%	2.1%
Station Hospitals									
General Hospitals									

TABLE V

TO COMPARE TOTAL ANESTHESIA "DEATH RATE" OF SEPTEMBER, 1943, WITH THAT OF SEPTEMBER, 1944

Time of Survey	Number of Institutions Included in Survey	Total Number of Anesthesias in the Sample	Total Number of Anesthesia Deaths*	Over-all Anesthesia "Death Rate" (Round Numbers)
September, 1943.....	12	7,650	8	1:1,000
September, 1944.....	10	19,914	4	1:5,000

\* What constitutes an anesthesia death can in most cases be argued over. Cases were described as "anesthesia deaths" in this study when they occurred without adequate explanation in the condition of the patient or in the surgery involved and followed a pattern known to be characteristic of the given agent. In several of these cases, death occurred unexpectedly either before surgery had started or very soon after its beginning. The same criteria were used in the two surveys made a year apart.

*Notes on the Use of Sodium Pentothal.*—While the action of this agent cannot be discussed in detail here, those employing it should, for safety, be aware that among other effects pentothal (as do all barbiturates) destroys the sensitivity of the respiratory center<sup>3</sup> to its normal chief stimulus, carbon dioxide. Under full pentothal anesthesia the body has to make use of a supplementary mechanism in order to keep respiration going. To maintain it, a shift is made from the normal driving action of carbon dioxide acting on the respiratory center to the action of anoxia on the chemoreceptors, chiefly the carotid mechanisms in the neck. Anoxia will stimulate respiration just as powerfully under deep pentothal anesthesia as it will under light anesthesia. Thus, the uninformed anesthetist may believe that respiratory stimulation under pentothal means that the patient is waking up, whereas, it may simply mean that the patient is not getting enough oxygen. A wrong interpretation, here, leading to the further administration of sodium pentothal, has probably caused deaths. In other words, the true depth of pentothal anesthesia may be impossible to determine when the oxygen content of the blood is low. For safety, certainly whenever the operation exceeds a half-

hour, oxygen ought always to be administered with pentothal, for, when the patient's oxygenation is normal, the character of the respiration is a helpful guide as to the depth of anesthesia. When the patient's oxygenation is below normal the character of the respiration may be fatally misleading.

TABLE VI

TO COMPARE PENTOTHAL "DEATH RATE" OF SEPTEMBER, 1943, WITH THAT OF SEPTEMBER, 1944

Time of Survey	Number of Institutions Included in Survey	Total Number of Pentothal Anesthetics in Sample	Total Number of Pentothal Deaths	Over-all Pentothal "Death Rate" (Round Numbers)
September, 1943.....	12	2,672	6	1:450
September, 1944.....	10	11,136	2	1:5,500

TABLE VII

ALTHOUGH GREAT IMPROVEMENT HAS BEEN MADE IN ANESTHESIA "DEATH RATE" THIS HAS NOT BEEN AT THE EXPENSE OF ABANDONING PENTOTHAL, RATHER ITS USE HAS INCREASED

Time of Survey	Forward Field and Evacuation Hospitals		Rear Station and General Hospitals	
	Number	% of Total	Number	% of Total
September, 1943.....	2,500	53%	1,462	28%
September, 1944.....	6,721	62%	4,415	48%*

\* This great increase is in large part to be explained by the adoption of the practice of secondary suture of wounds. Pentothal approaches the ideal anesthetic for this procedure.

Not only does the respiratory center lose its sensitivity to carbon dioxide under full pentothal anesthesia, but under such circumstances carbon dioxide becomes a true depressant. It is clear that the use of carbon dioxide to stimulate respiration depressed by too much pentothal is contraindicated.

Acceptable practice in the employment of sodium pentothal includes the use of 2.5 per cent solution, routine administration of oxygen, and frequent observation of pulse and blood pressure during anesthesia. In general, pentothal anesthesia is not the best choice for operations that will exceed a half to three-quarters of an hour in duration. If the duration of a given operation unexpectedly turns out to be longer than this, it is almost always well to shift to ether anesthesia.

It is probable that the course of pentothal anesthesia can be considerably influenced by the *preanesthetic medication*. There are many controversies concerning this. Morphine may or may not be used. Very likely preliminary morphine can lessen the total quantity of pentothal needed for a given procedure. Whether or not too high a price may be paid for this advantage is not certain at this time. (Does morphine heighten the activity of the occasionally troublesome laryngeal reflexes? Does morphine in reasonable dose play a part in the long depressions sometimes encountered following the use of pentothal?—*etc.*). It has been demonstrated that the supplement of pentothal anesthesia by inhalation of 50 per cent nitrous oxide with 50 per cent oxygen can reduce the dose of sodium pentothal required, probably a better means of accomplishing the desired end than by use of morphine.

Of considerably more importance than morphine in preliminary medication for pentothal anesthesia is atropin. Its purpose is to minimize vagal reflexes. Atropin 0.6 mg. (gr. 1/100), subcutaneously, should be given about one hour preceding induction of pentothal anesthesia, with half the dose of atropin repeated intravenously just before anesthesia is started. During periods of heavy admission of patients, there will not be time for the above and atropin 0.6 mg. (gr. 1/100) intravenously, about 10 minutes preceding anesthesia is satisfactory. (In the presence of severe tachycardia atropin is avoided). When laryngeal spasm occurs during pentothal anesthesia, atropin, 0.6 mg. (gr. 1/100), should be given intravenously as soon as possible, even though the same dose has been administered in preanesthetic medication shortly before this.

*The Clinical Choice of Pentothal Anesthesia.*—Changes here, effected over the Theater as a whole, have been of great importance in the reduction of the frequency of death under pentothal anesthesia (Table VI).

Sodium pentothal is of proven value in military medicine, of that we can be certain. Equally certain it is that the choice of pentothal is unwise, in the long run, in the presence of certain injuries:

(A) When the patient is suffering from morphine overdose avoid the use of sodium pentothal.

(B) When shock is present, or when shock is anticipated, avoid pentothal anesthesia. This should also be the case whenever the intake or distribution of oxygen is impaired or even jeopardized. The agent should rarely if ever be used when penetrating wounds of the thorax or the abdomen, or compound fractures of the femur are present. Severe hemorrhage, even when from otherwise trivial wounds, contraindicates pentothal anesthesia. Ether is the choice when these conditions are present.

(C) Sodium pentothal is a dangerous agent to use when cervical inflammation is present. Many deaths have occurred during surgery here. Apparently, inflammation in the region of the carotid bodies and sinuses causes sensitization of reflexes arising there. These may account for the notorious incidence of sudden death under such circumstances. Since pentothal (and other barbiturates) are not very effective in depressing these reflexes its choice should be avoided in most cases of this kind. Rarely, as in cases where compound fractures of the face may also be present and make inhalation anesthesia difficult sodium pentothal is sometimes the reasonable choice for the surgery of cervical abscess. When this is to be undertaken, the following precautions are to be observed: (1) Use heavy atropinization in the preanesthetic medication. (2) No surgery is to begin in cases with irritable carotid sinus until at least ten minutes following induction of pentothal anesthesia. (3) Avoid pressure on the carotids. If feasible, block them with local anesthesia.

(D) Sodium pentothal is not a good choice of anesthetic to make when

gas gangrene is present, for the toxins elaborated in this disease produce severe circulatory damage. Such damage contraindicates use of the agent.\*

So far, groups of cases have been discussed where pentothal anesthesia is contraindicated. In the following, the use of pentothal may at times be debatable; but it is usually unwise:

(A) In general, pentothal should be avoided when the operative position or procedure may interfere with the air-way or make artificial respiration difficult, as in operations that must be carried out in the face-down position, or in operations on maxillofacial injuries involving the air-way. If local anesthesia is inadequate, often the case, ether can be used, preferably with intratracheal intubation.

(B) While skillful (or lucky) anesthetists may often get away with the use of pentothal as the chief anesthetic agent for intracranial surgery, its employment here is usually unwise for the following reasons: (1) Such operations are long.† Pentothal anesthesia is best limited to short, half-hour, procedures. (2) Neurosurgical operations are usually associated with great blood loss, often a liter or more by actual measurement. Extensive blood loss contraindicates the use of sodium pentothal. (3) Sodium pentothal often unexpectedly causes respiratory depression and anoxia. Anoxia produces immediate swelling of the brain and may make an intracranial procedure difficult or impossible. The hiccupping, laryngeal spasm, and straining occasionally encountered under this agent or during recovery from it are particularly undesirable in intracranial surgery. Local procaine or ether is the best available choice in most of these cases.

(C) Experience with severe burns appears to show that such patients tolerate pentothal anesthesia poorly. Why this is so is not clear. (Perhaps the rather poor tolerance of these patients for pentothal is to be explained as a result of the great reduction of circulating blood volume in burns, with consequent circulatory impairment, in this respect like the effect of hemorrhage, known to contraindicate pentothal.)

The great field where pentothal has proved its value in military medicine, is in providing anesthesia, when relaxation is not needed, for short (half-hour) procedures in men in good general condition.

#### LOCAL AND REGIONAL BLOCK ANESTHESIA

These are accomplished chiefly with *procaine hydrochloride* (*pontocaine*)

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\* While it is true that the skin temperature of an extremity rises under anesthesia with sodium pentothal, this may be the result of an effect on arteriovenous anastomoses, and does not necessarily imply a better cellular oxygen supply. Polderman, McCarrell and Beecher (The Effect of Anesthesia on Lymph Flow. Jour. Pharmacol. and Exper. Therap., 78, 400, 1943) have shown that the lymph flow is greatly reduced by barbiturate anesthesia, in comparison with local or ether anesthesia. This can be construed as evidence that tissue oxygen supply is impaired by barbiturate anesthesia, certainly to be avoided in gas gangrene.

† Twenty typical craniotomies performed in the combat zone required on the average  $109 \pm 11$  minutes (not including anesthesia induction time).

or *cocaine* for topical anesthesia) for neurosurgical, some maxillofacial and for minor surgical procedures. Peritoneal block under direct vision is useful for improving abdominal wall relaxation under light ether anesthesia. Because of the usual multiplicity of wounds in a given individual, regional block procedures are often of little value in the combat zone. Notable exceptions here are paravertebral or intercostal blocks for controlling chest wall pain and sympathetic blocks when the circulation of an extremity is impaired.

TABLE VIII  
EVACUATION HOSPITALS

Hospital	Capacity Listed	Number of Patients at Time of Survey	Fluctuation In Number of Operations Per Day at Time of Survey	Anesthetists				
				M.D.	Nurse	Auxiliary Surg. GP.	Corps Men	Miscellaneous
"A"	750	800	25-100	1	2	0	4 plus 3 more on 2nd call	7 tables in day 4 tables at night
"B"	400	600	25-120	2	3	3	2	6 tables day and night
"C"	750		50-100	1	4	4	2	8 tables day and night
				(1 physician and 5 nurses care for 50-case days; the 100-case days require the addition of 4 auxiliary surgical group anesthetists)				
"D"	400	550	60-138	2	4	4	1	
				(See above re-addition of auxiliary surgical group anesthetists)				
"E"	400	500	50-125	1	4		0	
			(with 6 intern- ists—2 auxilli- ary teams)	(125-case days require the addition of 6 internists and 2 auxiliary surgical anesthetists)				
"F"	750	400	80-120	1	4	0	0	6-8 tables
			(1 dentist— 4 internists)	(The 120-case days require the added help of 1 dentist and 4 internists as anesthetists)				
								24-hours day

#### SPINAL ANESTHESIA

The 20 per cent incidence of spinal anesthesia found in forward hospitals in the survey of September, 1943 (Table I) fell remarkably down to 3 per cent (Table II) a year later, and reflects the widespread realization and acceptance of the clearly demonstrated fact that spinal anesthesia is usually a poor choice for use in recently wounded men: The condition of the circulation, already precarious, too often deteriorates rapidly under spinal anesthesia. It is almost never acceptable for the initial surgery of battle casualties. This is of course true for the surgery of fresh trauma wherever it occurs. The current 3 per cent figure referred to as found in the forward zone represents, in considerable part, use of the technic for emergency appendicectomy and other conditions unrelated to warfare. Only occasionally can one find in this Theater an experienced surgeon, or anesthetist, who will now recommend the use of spinal in even the lightly, but freshly, wounded. This represents a striking change over the situation existing a year and a half previously.

#### TYPE OF SURGERY INVOLVED

An intelligent interpretation of anesthesia data requires that some key be given to the nature of the surgery involved. Such data have been presented in Table IV. Special groups, for example the Second Auxiliary Surgical Group, having a wide experience of forward surgery, particularly of non-transportable, field hospital patients, finds a higher incidence in certain categories than shown in Table IV. Major Lawrence M. Shefts has kindly supplied the writer with the following figures from his study of the files of the group referred to: In 15,925 cases, 1,628 (10.2 per cent) were classified as abdominal injuries, 1,502 (9.4 per cent) as chest cases with pleural involvement, and 508 (3.8 per cent) as thoraco-abdominal. The 1,628 cases listed as abdominal contain some "negative explorations"; so, as Major Shefts points out, the thoracic cases may be said to be as frequent as abdominal in this organization's experience. The combined total of chest and thoraco-abdominal cases exceeds abdominal alone.

#### PERSONNEL

The beginning of the present war found the country with too small a number of trained anesthetists and the Army Medical Corps, reflecting as it does a cross-section of American medical practice, shows this same shortage. For example in this Theater, of the men listed in the personnel files as "specialists in anesthesia," just 10 per cent have been certified by the American Board of Anesthesiology. Of the physician anesthetists in the Theater, 20 per cent had had no anesthesia training, except that obtained incidentally during surgical or rotating internships and a further 15 per cent had had only one to three months training in anesthesia.

The total number of physicians available for assignment to anesthesia was so small as to require the widespread use of nurse anesthetists for ether and sodium pentothal anesthesia. In a few cases corps men were needed and used to supplement the anesthesia staff in the forward areas. These men worked under close supervision.

Possibly more than any other single unpreventable factor the constant shortage of trained anesthetists was responsible for delay or threatened delay in carrying out needed surgery. While instances when shortage of anesthetists has seriously slowed down the flow of patients to surgery are relatively few, this was a constant and uncomfortable threat to those responsible for the care of the patients. That serious shortage was not more common was due to the voluntary aid of dentists, the assignment of internists to anesthesia duties and most important, the constant training of nurses in this work. Four general hospitals were employed for this purpose where courses up to three months were given, depending upon how long the students could be spared from their respective units. This was in addition to training given throughout the Theater in each unit for the training of its own members. The general hospitals, having more minor cases, were better suited than the forward installations for such supervised training.



The following tables (VI, VII, VIII) give typical sample data showing the personnel used in relationship to the load in various installations. An important group not represented in the tables is that of the field hospitals, these (for nontransportable patients), with their 100 bed capacity per platoon, usually are staffed with four mobile surgical auxiliary teams each of which includes an anesthetist, in most cases a physician. Two operating tables can be used day and night. Sometimes three or four operating tables are used at one time in a single platoon, but this number only for short intervals.

TABLE IX

## STATION HOSPITALS

Hospital	Capacity Listed	Number of Patients at Time of Survey	Aver. No. Operations Per Day at Time of Survey	Number of Nurse Anesthetists	Miscellaneous Anesthetists
"A"	250	348	3	1	Surgeons give spinals. One physician on part-time anesthesia duty
"B"	500	250	5	1	A part-time physician anesthetist also has a ward
"C"	500	400	4	2	
"D"	500		3	1	3 surgeons assist with anesthesia part-time
"E"	500	389	6.5	0	Medical officers take turns
"F"	250	490	15	3	
"G"	500	625	4.5	0	1 full-time physician anesthetist. 4 surgeons cover anesthesia on a part-time basis

TABLE X

## GENERAL HOSPITALS

Hospital	Capacity Listed	Number of Patients at Time of Surgery	Aver. No. Operations Per Day at Time of Survey	Physician Anesthetists	Nurse Anesthetists	Miscellaneous
"A"	1,500	900	10	1	2	2 anesthesia utility men help out with apparatus (do not give anesthesia)
"B"	1,500	1,700	50	1	6	
"C"	1,500		25	1	3	
"D"	1,500	1,000	10	1	2	1-2 internists help when needed
"E"	1,500	950	13	1	3	

As a working principle it is always better to give the ablest anesthetists assignment in the combat zone. Unquestionably, it is here that the greatest demands are made on native intelligence, judgment, resourcefulness and technical ability. Often in practice, however, this principle could not be put into operation, because of the association of outstanding men with affiliated units having their origin in various schools or hospitals. These men could not be readily transferred. In several instances their unusual abilities were utilized for training anesthetists to be sent to the forward areas. It is probably true that the surgery undertaken in the rear (station and general hospitals) requires at least as much judgment, skill and training as that of the forward

zone, but the anesthetist's skill is certainly more heavily taxed in the forward region than in the rear.

#### SUMMARY AND CONCLUSIONS

In the prolonged campaigns that have been carried out in the Mediterranean Theater of Operations, ether has clearly emerged as the anesthetic agent of choice for use in the seriously wounded. Its corresponding merit in the less trying cases is evident.

Acceptance of the limitations of sodium pentothal, that is, avoidance of its use in recently badly wounded men and employment of it when relaxation is not needed, for relatively short procedures in men in good general condition, has made possible great reduction in the death rate attributable to the agent. At the same time its use has been increased. This demonstration, made possible by the anesthetists and surgeons of the Theater, constitutes a milestone in military medicine; for the agent, sodium pentothal, has been employed in warfare, its limitations for this purpose clearly defined, and on this basis the death rate reduced to a small fraction of what it had been. Sodium pentothal, thus, takes rank with ether and procaine (novocaine) as one of the three most important anesthetic agents for use in military medicine.

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# MUCO-EPIDERMOID TUMORS OF SALIVARY GLANDS

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FOR A NUMBER OF YEARS our attention has been directed to a group of salivary gland tumors differing structurally from commonly recognized tumors primary in these locations. Due to their infrequency and our inability to find adequate clinical and pathologic descriptions, these tumors for a considerable period constituted a several-sided problem as regards terminology, histogenesis and prognosis. Gradually, by correlating histologic structure with clinical course it became possible to dissociate two structural types, one indicating capability of localized growth, the other that of metastasis. A few of the tumors afforded unusual opportunity to establish their origin from salivary gland ducts and the group as a whole showed no structural interrelationship with other specific types of salivary gland tumors.

The term, "muco-epidermoid" salivary gland tumor, is one of our own choosing and, although not fully descriptive, it expresses two principal histologic features present in all of our cases. No pretense is made that these tumors are described herein for the first time. Beyond doubt both the old and more recent literature contain references to them but in a fashion insufficient for group analysis. It is certain that they deserve a more prominent place in the literature on salivary gland tumors than they now possess. We place their frequency at a little more than 5 per cent of all combined major and minor salivary gland tumors.

Lack of recognition and emphasis on these tumors is understandable. As a group they traverse an unusually broad range of histologic variation dependent upon the relative proportions of the different representative cell elements present, and tendencies to diffuse overgrowth by a single cell type. Gross appearance is not uniform. Sometimes the tumors are cystic and again they are solid. Some of them are encapsulated and others are not. The recurrent tumors may depart greatly from the structure seen in the primary. Unless analyses of salivary gland tumors encompass very large numbers of cases there is little probability that the full range of these muco-epidermoid tumors will be observed. It is likely that many of the tumors have been forced into classifications under such terms as "cystadenoma," "basalioma," "cylindroma," "squamous carcinoma" or "adenocarcinoma." Finally, there seems to be a certain reaction of frustration among pathologists which leads to relegating any odd salivary gland tumor to the broad, unfenced field of the so-called mixed tumor.

Lecène,<sup>1</sup> in a paper devoted to adenomas and cysts of the parotid salivary gland, showed an illustration, now difficult of interpretation, of a case bearing some resemblance to the group to be described. He regarded the tumor as different from mixed tumors. In this case Lecene stated that squamous

epithelium was absent; but the degree of alteration required before an epidermoid cell is referred to as squamous will vary among different observers. Fick,<sup>2</sup> in 1909, described and illustrated a probable case. He regarded this as an example of mixed tumor but the description rendered raises doubt as to this. Shortly after Lecène and Fick, in a discussion of cancer of the submaxillary salivary gland, Chevassu<sup>3</sup> reported a case that was probably of this muco-epidermoid type. It is interesting that he regarded the excretory ducts as the probable site of origin. Chevassu quoted an older case of Volkman<sup>4</sup> that seems equally probable. There is no doubt that a tumor described by Schilling<sup>5</sup> can be identified as a member of this group. His Figures 2, 3, and 4, taken from a single case, are entirely convincing. Krompecher<sup>6</sup> gives an account of a tumor of the lip that arouses speculation. In his opinion some tumors of mucosa and major salivary glands were of excretory duct origin. Ewing,<sup>7</sup> in his chapter on salivary gland tumors, lists several structural features that are common to muco-epidermoid tumors but presents no formal treatment of these as a separate histologic variety and simply includes them under the general heading of carcinoma. He regarded such tumors as ductal in origin. In Lang's<sup>8</sup> treatise on salivary gland tumors mention is made of a parotid tumor first classified as a round cell sarcoma but reclassified by Heineke as a papillary cyst carcinoma. Later this tumor was said by Schäfer to have contained mucous cells, and on this basis we may regard this as another probable case. Leroux and Leroux-Robert<sup>9</sup> in 102 major salivary gland tumors, found four with high cylindrical or clear mucous cells. Their photomicrographs show the presence of other cell types. These cases with little doubt correspond to the group to be discussed. These authors also speak of seven cases of "malpighian" type with squamous differentiation. It is difficult to ascertain if these cases represent mixed tumors with foci of squamous metaplasia or if they, too, are a type of muco-epidermoid tumor. Ahlbom,<sup>10</sup> in an extensive monograph devoted to salivary gland tumors, gives in collaboration with Reuterwall a thorough morphologic classification. Included in this are tumors listed as "papillary cystic." They are further designated as being benign, semimalignant and malignant. We would use the term, muco-epidermoid, certainly for some of these tumors, on the basis of Ahlbom's Figures 33 and 41.

Our review of literature related to salivary gland tumors has not included every article on this subject but it has been extensive with reference to important sources. Enough ground has been covered to give assurance that the type discussed in this paper has been dealt with very sparingly. These tumors are certainly not familiar objects. A great many of our sections have been shown to experienced pathologists who have expressed themselves as unacquainted with them as a specific group.

#### MATERIAL

The material for this analysis was obtained from the Memorial Hospital records of approximately 700 major and minor salivary gland tumors of all

types seen between 1928 and 1943. A total of 45 cases was found acceptable for inclusion. No case was selected in which it was not possible to demonstrate the presence of mucous cells, as shown by staining with Mayer's mucicarmine. In addition, every tumor had cells with epidermoid qualities—as will be defined in a later section. No case presented the structural characteristics of mixed tumors or other varieties of salivary gland tumors.

#### PATHOLOGY OF MUCO-EPIDERMOID TUMORS

*Histogenesis.*—In tracing the origin of muco-epidermoid salivary gland tumors it must be recalled that scattered mucous cells, though not uniformly present, can be found within the duct epithelium of a considerable number of major salivary glands. The same is true in minor salivary glands, but they are more difficult to demonstrate. Under normal conditions they are scarce and are more likely to occur within the lining of major excretory ducts. Their frequency decreases as the smaller duct radicals are approached and we have not observed them within intralobular ducts. Under pathologic conditions leading to chronic interstitial sialitis the number of mucous cells is apt to be greatly increased. During the course of this study we examined a large number of salivary glands that did not contain tumor but which had been removed on account of chronic interstitial sialitis. In such salivary glands mucous cells were almost invariably found, sometimes in such striking numbers that they formed small, hyperplastic foci. In sections of whole glands the frequency and distribution of mucous cell aggregates was correlated closely with the pattern of the interstitial inflammation. In such cases we failed to discover mucous cells as far down in the duct system as the intralobular ducts.

Other cells of the salivary gland ducts include the rounded basal or malpighian cells, rounded or elliptical intermediate cells and the columnar cells. The latter are almost invariably nonciliated but on two occasions we were able to detect cilia, once in the parotid and once in the submaxillary salivary gland. The major excretory ducts usually have three to four basophilic cell layers but these gradually decrease as the salivary gland lobules are reached. The intermediate ducts have two layers, basal and columnar. These gradually become attenuated so that the intercalary ducts do not have two continuous cell rows. The columnar cells become more in evidence until they constitute the only discernible layer. As a single columnar cell-lining is established the cytoplasm assumes an eosinophilic quality. This occurs shortly before the duct branches enter the lobules and within these structures the eosinophilic properties of the duct epithelium are maintained.

All of the evidence in our material points to the salivary gland ducts as the anatomic site of origin of muco-epidermoid tumors. Two of the tumors in our series were very small, measuring only a few millimeters in diameter. They consisted in scarcely more than a collection of dilated ducts containing papillary or nearly solid tumor composed of appropriate cell types. There

was no evidence in these cases (or in others) of acinar participation. In more advanced tumors it was not uncommon to find closely adjacent or even outlying ducts in which there were hyperplastic foci. Such foci were made up of cell types identical with those constituting the main body of the tumor. The existence of such outlying foci (Fig. 1) may in part explain the fact that even the more favorable histologic forms of muco-epidermoid tumors are more apt to recur after surgery than are mixed tumors. In one tumor, recurrent when first seen at Memorial Hospital, a protruding nodule was seen distending Stenson's duct. The patient had complained of bloody saliva. After surgical excision, the tumor proved to be exclusively intraductal. Though much emphasis in this case is lost due to the fact that the tumor was recurrent, we have never seen a recurrence present in this particular fashion when the tumor was a member of a different histologic group. The occurrence of various cell types in the ducts of salivary glands has already been mentioned and when it is found that a series of salivary gland tumors is composed of multiple cell types and when these cell types are seen to correspond structurally to cells found in a certain anatomic location it is reasonable to implicate such a site as the source of origin for these tumors. This set of relationships holds true as regards salivary gland ducts and muco-epidermoid tumors. Having failed to secure evidence of the participation of eosinophilic cells in the tumors under consideration, emphasis is placed on the origin of such tumors in the larger and intermediate ducts.

Separation of the tumors into two histologic types: Early in this paper it was stated that muco-epidermoid tumors could be separated into two histologic varieties and for convenience these will be referred to as benign and malignant. These designations, however, require qualification. It might be preferable to speak of a "relatively favorable" and a "highly unfavorable" group. The term "benign" is scarcely ever applicable in an absolute sense and as used here does not necessarily imply innocent behavior. It does mean that thus far we have not observed metastasis from such tumors. The term "malignant," when employed here, indicates a histologic structure which has been found associated with the ability to produce regional node and distant metastases. It, of course, does not mean that such an event is inevitable.

The authors freely admit that they suffered a long period of uncertainty as to the status of some of these tumors. Some initial impressions proved unreliable. These were corrected from time to time by checking histologic findings with clinical course. Finally, we began to catalogue cases in which metastases had been proven. Structural features in these tumors were studied and as these cases accumulated a practical working basis was formed for defining a known malignant group. Simultaneously, other cases were catalogued whose clinical course did not include the appearance of metastases. There remained a small number of cases of troublesome sort that were regarded with suspicion on account of a certain structural feature. This consisted of nearly diffuse epidermoid or squamous overgrowth of a quality

to be commented on in another section. Enough familiarity with these tumors has now been gained to be reasonably certain that they do not belong in a metastasizing group. There is a residual impression, none the less, that they are quite prone to recurrence and that some of these recurrences are definitely malignant.

In arranging material for the present study all of the slides were assembled in numerical order. Each was then estimated to determine whether or not it showed a malignant tumor. This was done without recourse to case histories. This analysis proved the validity of previously established histologic criteria of malignant behavior since on review of clinical records no case classified as "benign" furnished any evidence of metastasis. On the other hand, many of the cases classed as malignant had developed metastases. This dissociation of cases seemed necessary in order that the histologic and clinical traits of the benign and malignant tumors could be separately discussed.

*Cellular Interrelationships.*—Since, in the foregoing, a number of separate cell types have been mentioned as being present in muco-epidermoid tumors it can well be imagined that structural patterns will be numerous and varied. Before describing the microscopic patterns that characterize muco-epidermoid tumors it is desirable to discuss in some detail certain fundamental cellular proliferations and transformations that take place in these tumors. Whereas, they are seen with greater clearness in benign tumors, they are discernible in a considerable portion of malignant tumors. In addition to the study of the tumors themselves, observations of duct hyperplasias in glands free from tumor yield certain impressions concerning cell behavior.

The basal cells appear to be pluripotent and capable of differentiation directly into tall columnar epithelium or directly into rounded mucous cells. It also seems that the columnar cell may be a relatively fixed type or represent an intervening form prior to the assumption of mucus forming properties. In foci of orderly duct hyperplasia where there are many cell layers both columnar and mucous cell differentiation tend to occur at the luminal margin rather than at the basement membrane (Figs. 5 and 6). Thus, in such focal areas the middle zones are apt to be composed solely of intermediate or basal cells. Here and there, however, one may find some cells that have rather pale cytoplasm, are rounded and slightly or considerably larger than basal cells. The quantity of cytoplasm in these cells is increased and is pale in varying degree. If such sections are stained with Mayer's mucicarmine this pale quality of the cytoplasm marks the presence of mucus. The intensity with which the cells take the stain is variable and since mucus can be shown in round cells only slightly larger than basal cells it is evident that mucous change can occur without intermediate formation of large columnar cells. By similar means large columnar cells can be seen to acquire increasingly intense mucicarmophilic properties finally forming fully developed goblet cells.

The formation of columnar cells in these tumors may be referred to as the result of proliferation and differentiation, the latter term being chosen

FIG. 1

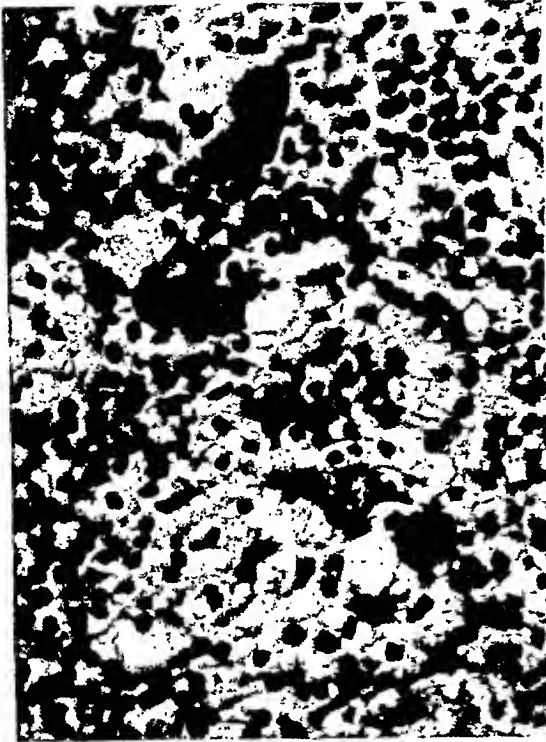


FIG. 2



FIG. 3

FIG. 4

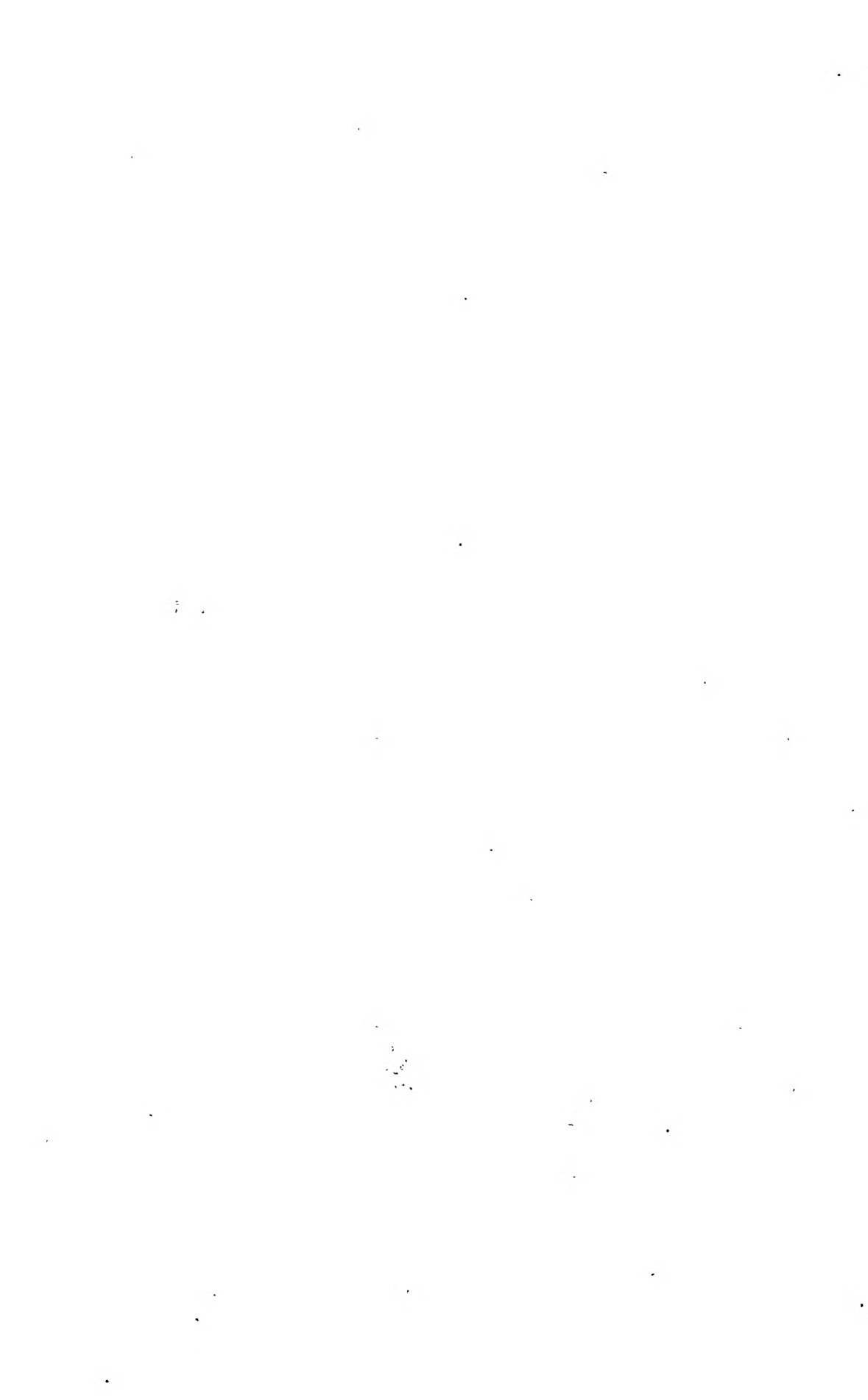
FIG. 1.—Periphery of a benign parotid tumor. Stratification and papillary hyperplasia of pink-staining mucous cells. (Iron hematoxylin, metanil yellow and mucicarmine.)

FIG. 2.—Same tumor as Figure 1. Diffuse epidermoid and squamous area adjacent to one rich in mucous cells.

FIG. 3.—Epidermoid and mucous cells in a malignant tumor of the parotid salivary gland. Regional nodes contained metastases.

FIG. 4.—Subcutaneous axillary metastasis from a primary tonsillar tumor. Large mucous cells, basal and intermediate cells. Note hydropic cells that do not take mucicarmine stain.





# MUCO-EPIDERMOID TUMOR

FIG. 5

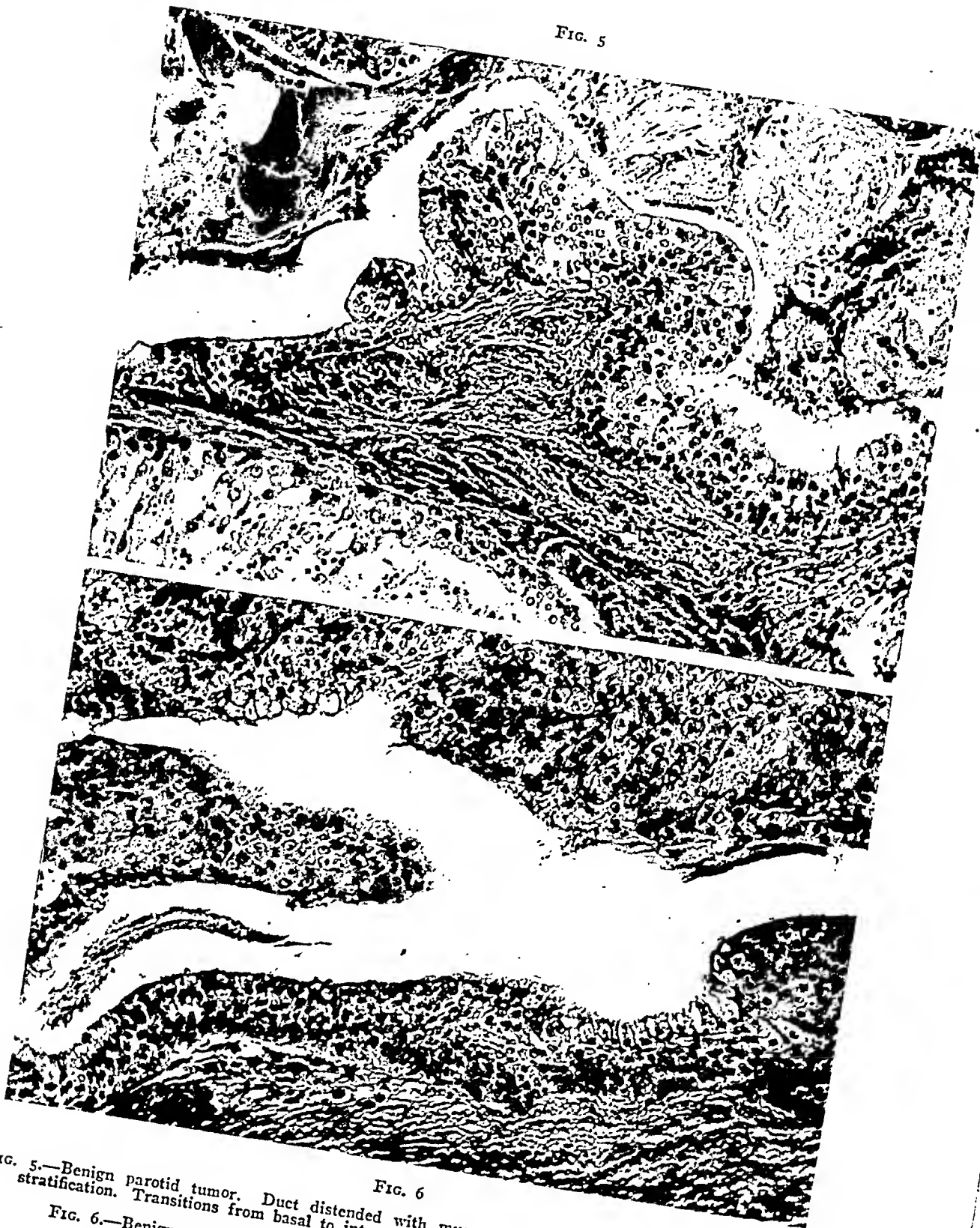


FIG. 6

FIG. 5.—Benign parotid tumor. Duct distended with mucus and cell debris. Varying degrees of stratification. Transitions from basal to intermediate and mucous cells. Two cells in mitosis.

FIG. 6.—Benign parotid tumor. Multiplicity of cell types discernible in limited area.

since columnar cells are distinctly normal constituents of salivary gland ducts. In neither the benign nor the malignant tumors are columnar cells a prominent feature quantitatively. In no case were they a dominant element and in an over-all sense they were few. Perhaps this cell type, when formed, has relatively limited powers of proliferation or perhaps the basal cells tend to lose their ability to differentiate into this form.

Since mucous cells are very sparse in normal salivary gland ducts their presence in muco-epidermoid tumors may be referred largely to a process of metaplasia, that is, abnormal differentiation. Initially, it is presumed that the basal cells furnish the chief source of mucous cells. There is much evidence, however, that mucous cells, once formed, have considerable powers of proliferation. Very large as well as limited areas in some of the tumors were made up chiefly of this cell type. Mitoses in such areas were very rare and it is not easy to point out a single cell in mitosis and declare with assurance that it is or is not a mucous cell. In the upper, central portion of Figure 5 are two cells, probably of mucous type, in mitosis. In mucicarmine preparations occasional cells in mitosis have been observed to exhibit distinctly pink cytoplasm. Quantitatively, mucous cells were much more conspicuous in the benign than in the malignant tumors. In those dominantly mucous cell tumors epidermoid cells were by no means as plentiful as the basal or intermediate type.

Epidermoid metaplasia is one of the outstanding cytologic characteristics of both classes of muco-epidermoid tumors. Whereas, the basal cells are by all odds the principal type involved in this transformation there is satisfactory evidence from a good many tumors that both mucous cells and columnar cells may also undergo similar changes. Epidermoid metaplasia of basal cells when all stages are studied is an extremely gradual process and the first alteration involves slight enlargement of the cell due principally to increase in cytoplasm. In many tumors considerable areas of this sort of intermediate differentiation are seen and at this stage we have often employed the term "intermediate cell" to distinguish between the basal cell and one which possesses more definite epidermoid appearance. Further progressive change involves continued enlargement of cells and loss of uniform, round or oval cytoplasmic border. Certain cells assume a polygonal outline (Fig. 6, upper right), the nucleus becomes a little larger and more vesicular. At this stage the epidermoid cells are about twice the size of basal cells. If the process of metaplasia proceeds further, the cytoplasm becomes increasingly abundant and more opaque. With this degree of change the epidermoid cells are three to four times the parent cell size and can actually be described more accurately as possessing squamous characters (Fig. 12, lower left). In such cell areas as this it is not uncommon at high magnification to detect canalicular channels between the cytoplasmic limits of adjoining cells but when such structures are seen they are very seldom accompanied by the formation of intercellular bridges. Fully developed squamous differentiation with development of keratohyalin granules, intercellular bridges, and pearl formation

are seen in the exceptional case with great clearness (Fig. 8). When epidermoid and squamous metaplasia stem from columnar or mucous cells the process is not sufficiently different from that already described to justify repetition. Cells that have differentiated along epidermoid or squamous lines seem to develop greater powers of proliferation than those which have become columnar or mucous. Diffuse epidermoid overgrowth occurs in both the benign and malignant tumors sometimes to such an extent that multiple sections and mucicarmine staining are necessary before they can be classed in the group under discussion.

#### HISTOLOGY OF THE BENIGN TUMORS

In the 26 benign tumors the predominant cells were epidermoid in 14, mucous in nine and intermediate or basal in the remainder. In the majority at least three cell types were represented. Tumors that included appreciable numbers of every cell type described were rather exceptional even when many blocks of tissue were sectioned. The presence of multiple cell types in large numbers was more distinctive of benign than malignant tumors.

The most highly characteristic tumors (Fig. 6) are necessarily those which contain reasonably large numbers of all of the various cell types described. Seldom does one see an area of even a few millimeters in which these various cells are present in equal number. In a restricted area pattern depends a good deal on which type of cell is predominant. For example, if the basal or intermediate cells predominate, a uniform mosaic results and the constituent cells tend to be arranged in quite small to quite large sheet-like groups which may make up only a small part of a low power field or may encompass an area many times as large. The peripheral margins of such cell masses are usually quite clearly delineated somewhat as is seen in basal cell epithelioma or sweat gland adenoma. In such areas solid growth is the rule and if there are openings or pseudoglandular spaces, other cell types are almost invariably present.

In areas particularly rich in mucous cells the above-described sheet-like growth quality is unexpected (Figs. 5 and 7). Instead there are quite small or even greatly dilated duct-like structures which are lined sometimes by several, oftentimes by a single cell layer. Here and there will be knob-like epithelial excrescences whose cell members, though chiefly mucous in type, are seldom exclusively so. Some areas of mucous cell preponderance assume distinctly papillary qualities but these papillae only infrequently possess a central core of vascularized fibrous tissue. In other words, true papillary cystadenomatous structure is uncommon. When such structure is present, nonmucoïd columnar cells are apt to be seen in their greatest frequency. In those portions of tumor which are duct-like or cystic the greatest multiplicity of cell types is apt to be encountered. Such areas, whether they are of microscopic or macroscopic size, are commonly found partly or entirely filled with mucoïd secretion (Fig. 5) which stains brilliantly red with Mayer's mucicarmine (Fig. 1). Such "mucus pools" were found in about one-half

FIG. 7

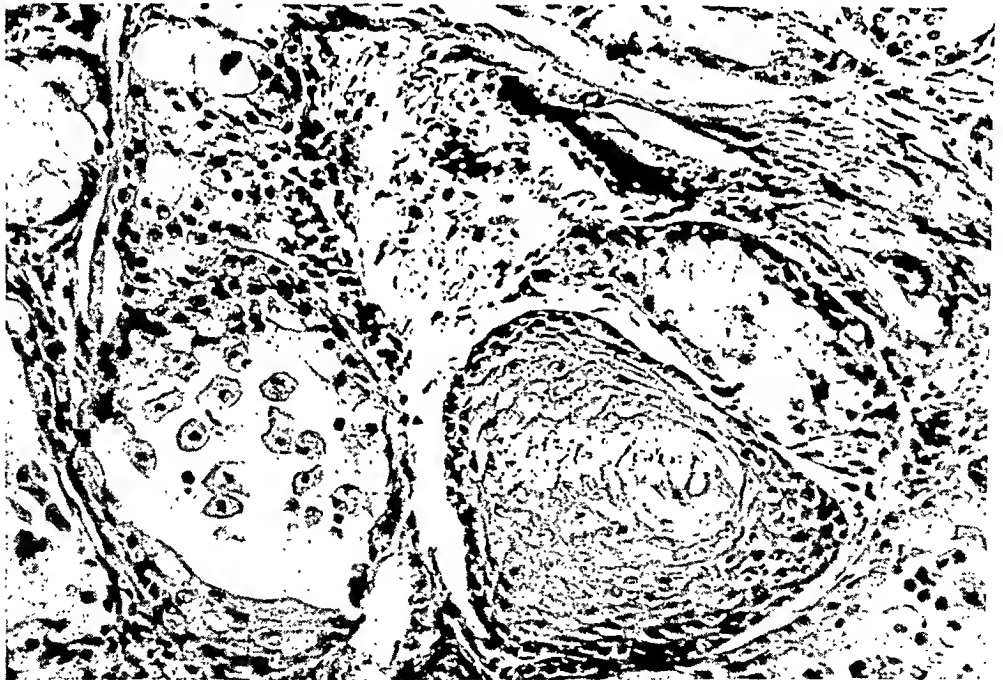
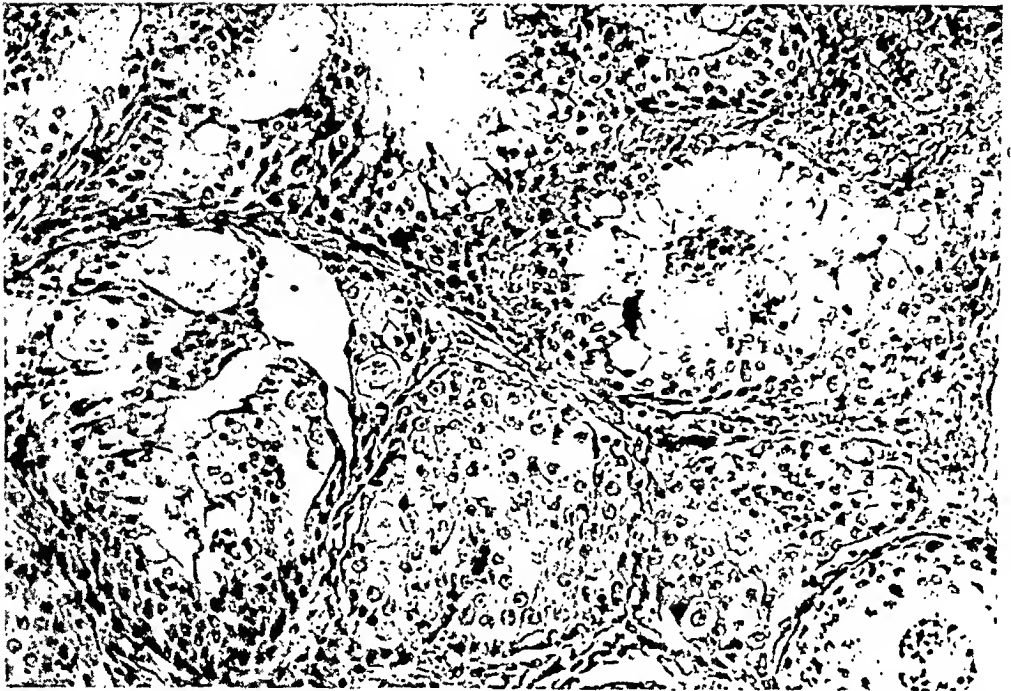


FIG. 8

FIG. 7.—Structure commonly seen in benign tumors. Mucous and epidermoid cells in abundance, the latter assuming some squamous qualities. Small numbers of basal and intermediate cells, their distinction not easy. Primary parotid tumor.

FIG. 8.—Benign tumor of tongue. Squamous pearl in a predominantly mucous cell area.

of the benign tumors. As a result of overproduction of mucus, considerable dilatation commonly ensues and the result of this is the erosion of lining epithelium, disruption of basement membrane, and leakage into adjacent tissue (Fig. 10). If this takes place in a near solid portion of tumor, small or larger areas of necrosis result. If there is leakage into an area where there is considerable interstitial tissue, a marked secondary inflammatory process is likely to ensue. Hence, in tissue adjacent to ruptured "mucus pools," it is not uncommon to see a well-developed foreign body reaction with formation of multinucleated giant cells.

In studying foci made up chiefly of epidermoid cells (Figs. 6 and 9), it is unusual to find complete dissociation from basal or intermediate cells but if the epidermoid differentiation has developed further so as to assume squamous qualities, there is apt to be extremely diffuse unicellular overgrowth. In such diffuse areas there is a certain monotonous regularity of structure difficult to describe but of a distinctly different type than that seen in squamous carcinoma in the usual sense. There is greater similarity in cell size and shape, staining qualities are quite uniform, and mitoses are few. It is in such areas as these that one is apt to regard the tumor as malignant and considerable familiarity with its structure is needed before one feels confident of expected clinical behavior (Fig. 2, lower half). In the benign tumors, the squamous areas referred to above tend to grow in relatively large sheets and plugs but in some tumors these become quite small and in the process of fixing and dehydration, shrinkage is apt to cause contraction so that the epidermoid or squamous plugs give the false impression of lying within lymphatics. Whereas this false impression of lymphatic invasion is usually easily settled by careful high-power study adjacent connective tissue cells are sometimes capable of simulating flattened endothelium.

Before concluding this description of microscopic features an additional cytologic alteration should be described. In about a third of the benign tumors, certain areas were composed of cells that appeared hydropic and swollen. They had extraordinarily clear cytoplasm (Fig. 11). When this change was highly developed and the cells in alveolar or pseudoglandular grouping, there was effective mimicry of clear cell renal adenocarcinoma. Since the collection of material for this paper we have seen a biopsy of a submaxillary tumor in which this structure was so prominent that it was necessary to have assurance that there was no clinical evidence of renal neoplasm before making the diagnosis of muco-epidermoid salivary gland tumor. Sections of the excised tumor eliminated any doubt of its muco-epidermoid nature. When these hydropic changes are present, they might lead one to suspect that such areas had undergone mucous transformation. In none of our cases, however, did such cells stain with Mayer's mucicarmine.

To sum up, in any benign tumor there may be a very wide range of structural variation dependent upon the frequency of individual cell types and the growth pattern that such cells seem to follow. This is further modified by the presence of secondary phenomena such as overproduction of

mucus, distention of canalicular components, secondary interstitial inflammation, and spontaneous necrosis.

#### HISTOLOGY OF THE MALIGNANT TUMORS

An over-all analysis of the cytology seen in the malignant tumors showed rather definite trends. For example, in none of this group of 19 tumors did mucous cells predominate, and in only eight of these were mucous cells the second most frequent element. Epidermoid cells were dominant in 14 of the 19 tumors (Figs. 3, 12 and 13). It is understood that the term epidermoid, as used here, includes cells which resemble those seen in basal cell carcinoma and also those cells which have been described as resembling squamous cells without intercellular bridges and keratohyaline granules. Another frequent cellular component of the malignant tumors was the intermediate cell which, it must be admitted, is difficult to distinguish verbally from the basal cells other than by saying that they are slightly larger, have somewhat more vesicular nuclei and more abundant cytoplasm (Fig. 17). Columnar cells, as in the benign tumors, were infrequent in the malignant tumors. When present they were not numerous. In one tumor it was possible to identify a few ciliated columnar cells. True squamous cells having intercellular bridges and epithelial pearls were found in five cases. There were four other cases in which intercellular bridges alone were present.

When the malignant tumors and benign tumors are studied as individual groups wide structural divergences are apparent. There is, however, an undertone of similarity varying in degree from case to case. Now and then a case is met in which a remarkable series of cellular alterations has occurred so that the entire gamut of changes characteristic of both the benign and malignant types is seen. If, however, one studies a highly mucoid and epidermoid tumor of the benign group and then one of the very diffusely overgrown rather anaplastic malignant tumors, he would probably not be very much impressed by the interrelationship of these two types of muco-epidermoid salivary gland tumors. Further means of integrating the benign and malignant tumors as members of the same fundamental group are secured by studying structural changes in succeeding recurrences. In several cases the initial structural characters were those of a benign tumor made up of mucous and epidermoid or squamous cells in orderly arrangement. In recurrences, diffuse epidermoid overgrowth has taken place together with the development of atypical cell qualities such as characterize the malignant tumors. The scope of changes observed in the transformation of a benign into a malignant muco-epidermoid tumor traverses no wider range of structural alteration than may be met in the case of a mixed tumor of salivary gland which has become malignant. It must be emphasized that the large majority of malignant muco-epidermoid tumors do not contain residual microscopically benign elements. We were at first skeptical about including some tumors in the malignant group but were finally convinced of their suitability after having studied that material which showed transitional

phases. Due to almost complete overgrowth by epidermoid or squamous cells many of the tumors are apt to be regarded as unicellular cancers of either epidermoid or squamous type. In such cases, however, careful study will reveal small nests, minute groups or even single cells of different sort. Some isolated cells which appear rather pale but finely granular can be proved by mucicarmine staining to contain mucus. It is repeated that no tumor has been included in this series in which a mucicarmine stain was negative. We believe in all probability that a certain number of rather anaplastic and diffuse cancers of salivary glands are fundamentally muco-epidermoid in type but have become so overgrown that the mucous element is no longer discernible. This is perhaps especially true in that group of salivary gland tumors referred to by most observers as squamous or epidermoid carcinoma. In our own material we have quite a number of such tumors but when they have proceeded to this degree of homogeneity, we have excluded them from consideration here.

The histologic qualities which separate the malignant from the benign tumors are for the most part easily recognized. These traits are not substantially different from those ordinarily present in epidermoid and squamous carcinoma and as such do not require further comment (Figs. 13 and 16). The remainder of the malignant tumors may exhibit these qualities in slight or moderate degree but their outstanding characteristic is diffuse proliferation of rather small, moderately hyperchromatic, rounded and oval cells in sheet-like arrangement with tendency to palisading of the outer layer of cells which surround the proliferating sheets and pegs of tumor (Fig. 15). A general structural impression is that of the gross pattern of a basal cell epithelioma with something added. There is appreciable resemblance to some of the highly cellular transitional cell carcinomas of other locations. Rather than continuing in the effort toward verbal descriptions, it is preferable to refer the reader to Figures 12, 13, 15-18.

Other structural differences become evident when comparing the benign and malignant tumors. The latter show little tendency to formation of microcysts. Tubular and papillary features are far less frequent. Over-secretion of mucus with the production of mucus pools practically never occurs. For obvious reasons secondary inflammatory changes, referable to the leakage of mucoïd material, are highly exceptional. Sometimes present in the malignant tumors are pseudoglandular structures. These are by no means common. In one case having such structures they were partly composed of mucous cells. In this case some portions were hard to separate on structural grounds from mucous gland adenocarcinoma.

Analysis of the histologic structure of the metastatic tumors revealed some points of interest. The variable structure of the primary tumors was sharply reflected in such lesions. By way of illustration, on more than one occasion the metastatic lesions were distinctly more epidermoid or squamous than the primary. The reverse of this was also seen. Moreover, in a single metastatic nodule considerable variation was observed (Figs. 16 and 17).



FIG. 9

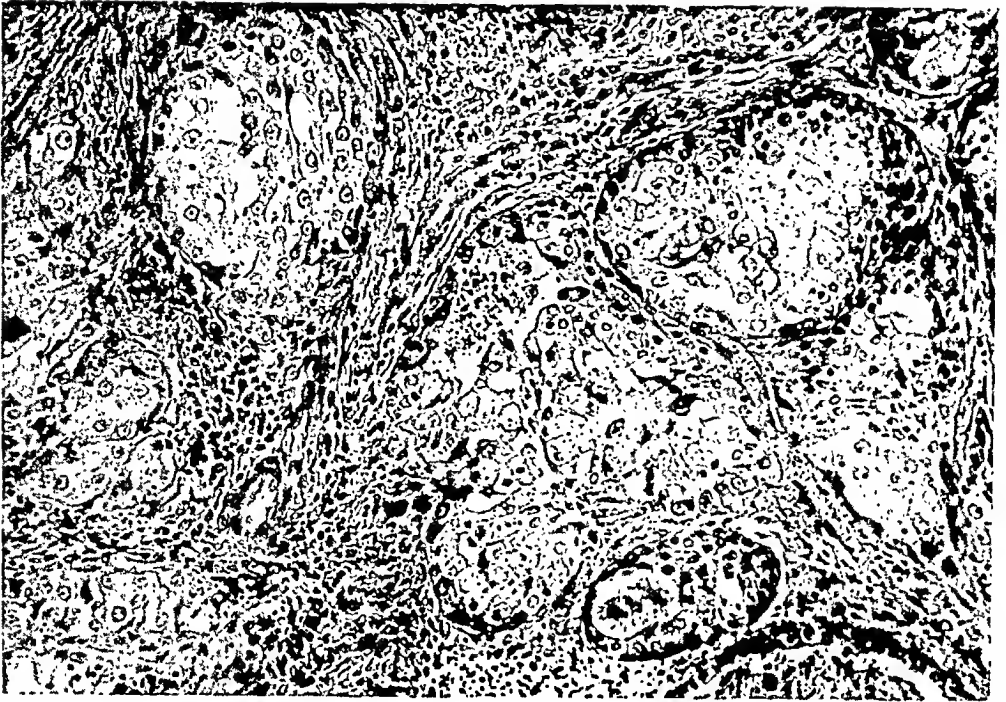


FIG. 10

FIG. 9.—Benign tumor of parotid. Cellular make-up largely epidermoid but showing intermingled mucous and basal cells.

FIG. 10.—Erosion of epithelium, leakage and interstitial inflammation.

# MUCO-EPIDERMOID TUMOR

FIG. 11

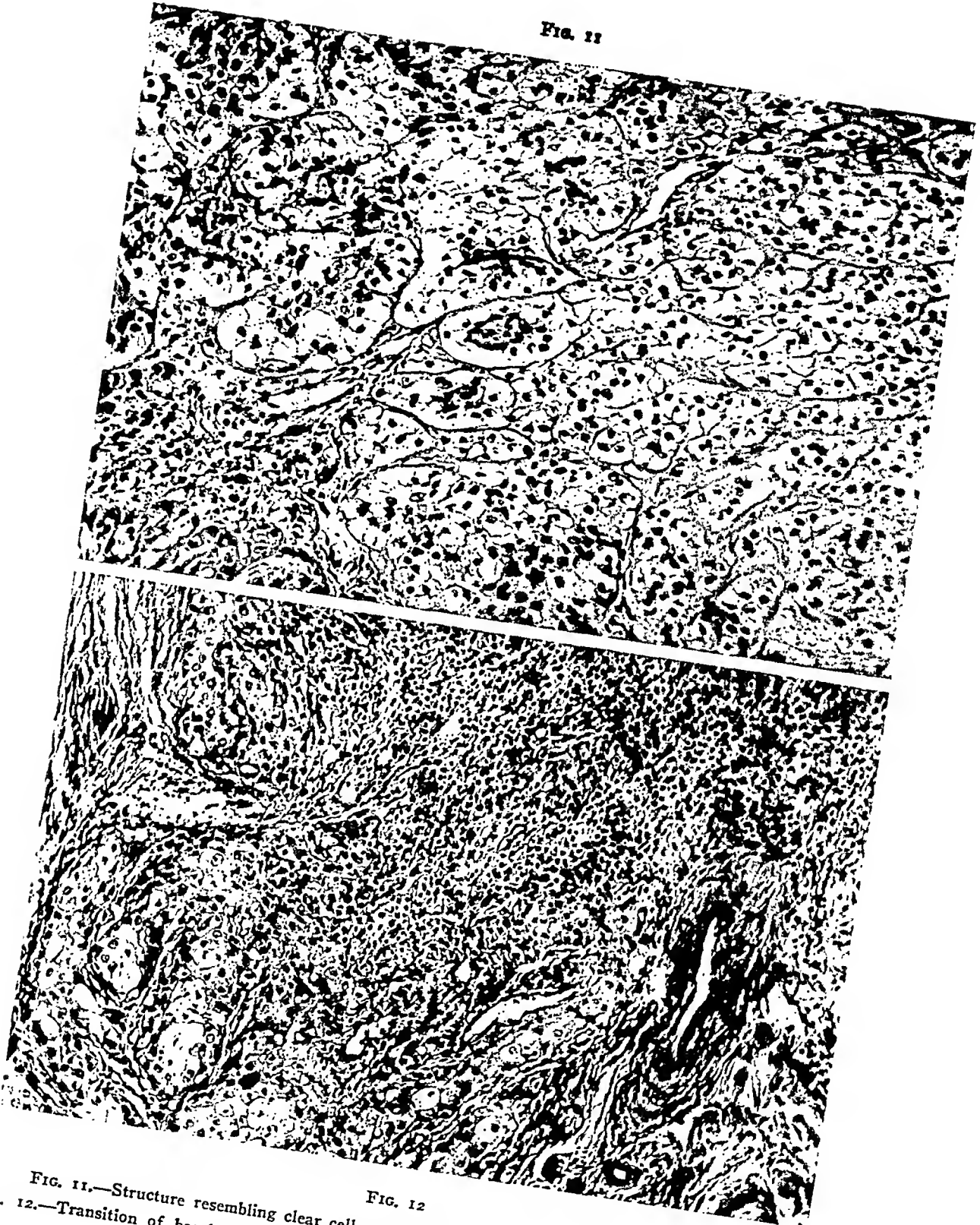


FIG. 12

FIG. 11.—Structure resembling clear cell renal adenocarcinoma. Regarded here as benign.  
FIG. 12.—Transition of basal to epidermoid and squamous cells in a malignant parotid tumor with multiple cervical node metastases.

FIG. 13.

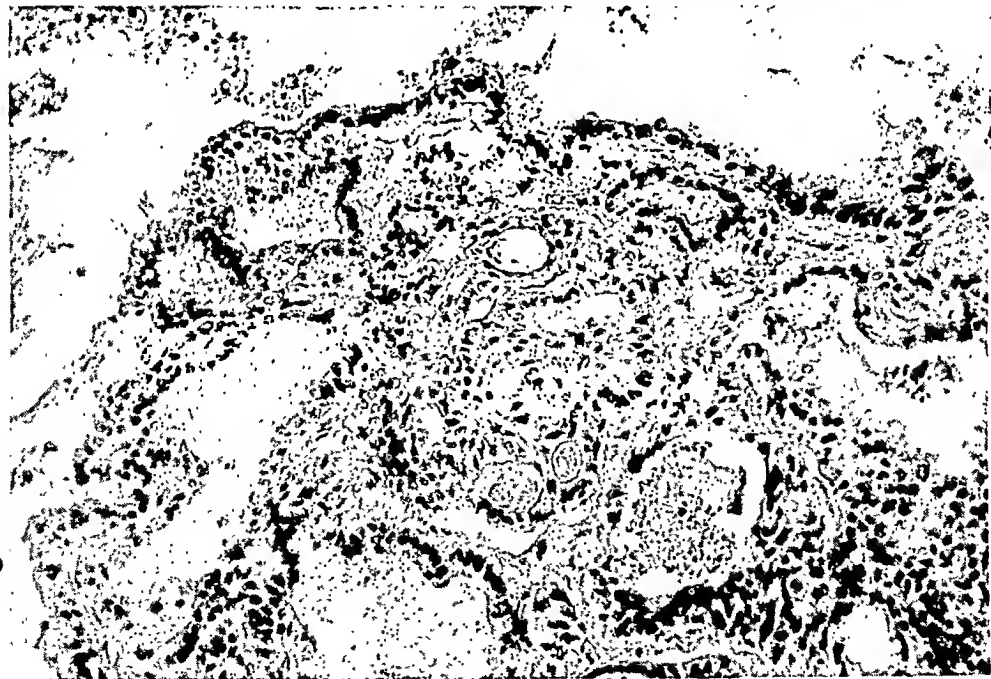
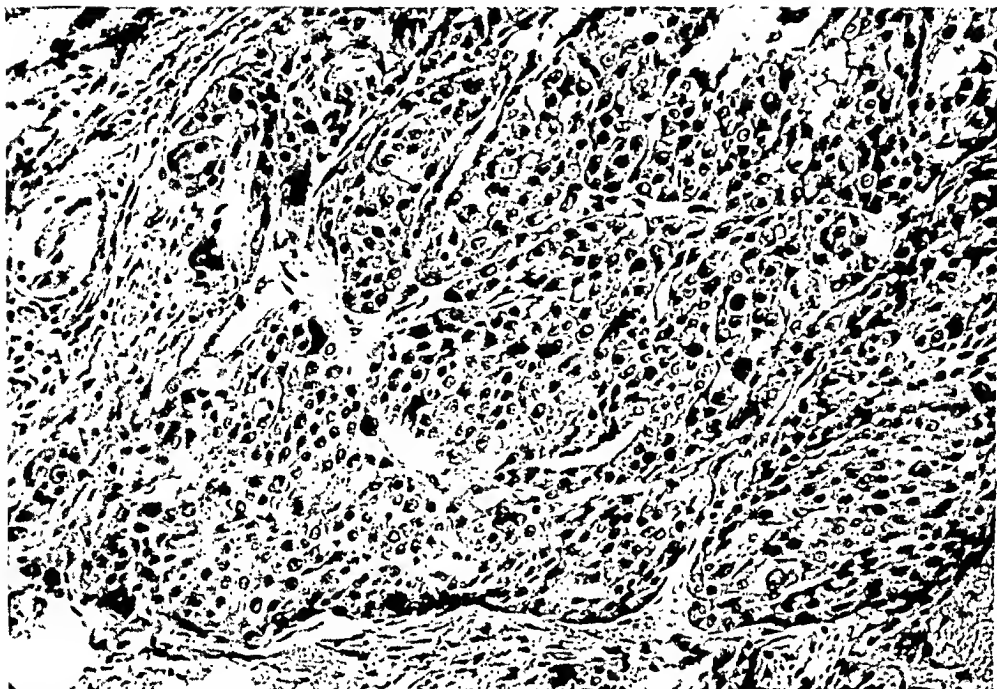


FIG. 14

FIG. 13.—Portion of an alveolar ridge tumor. Present for 25 years. Malignant transformation with structure of epidermoid carcinoma. (See also Figure 14.)

FIG. 14.—Another area of tumor shown in Figure 13. Growing here as papillary cystadenoma, benign.

FIG. 15

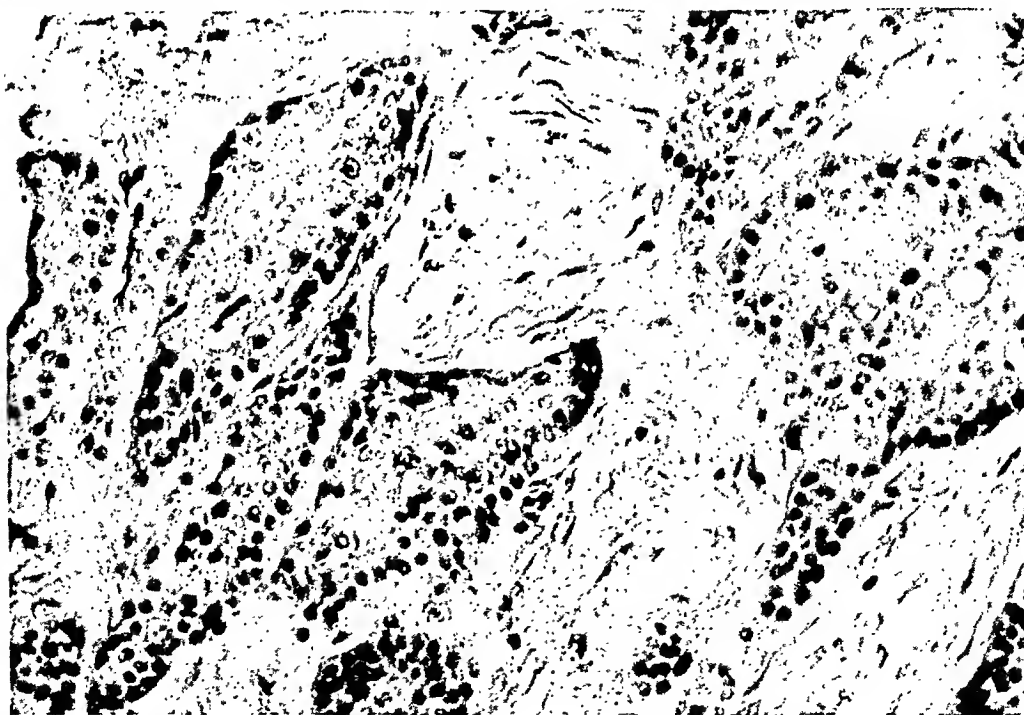
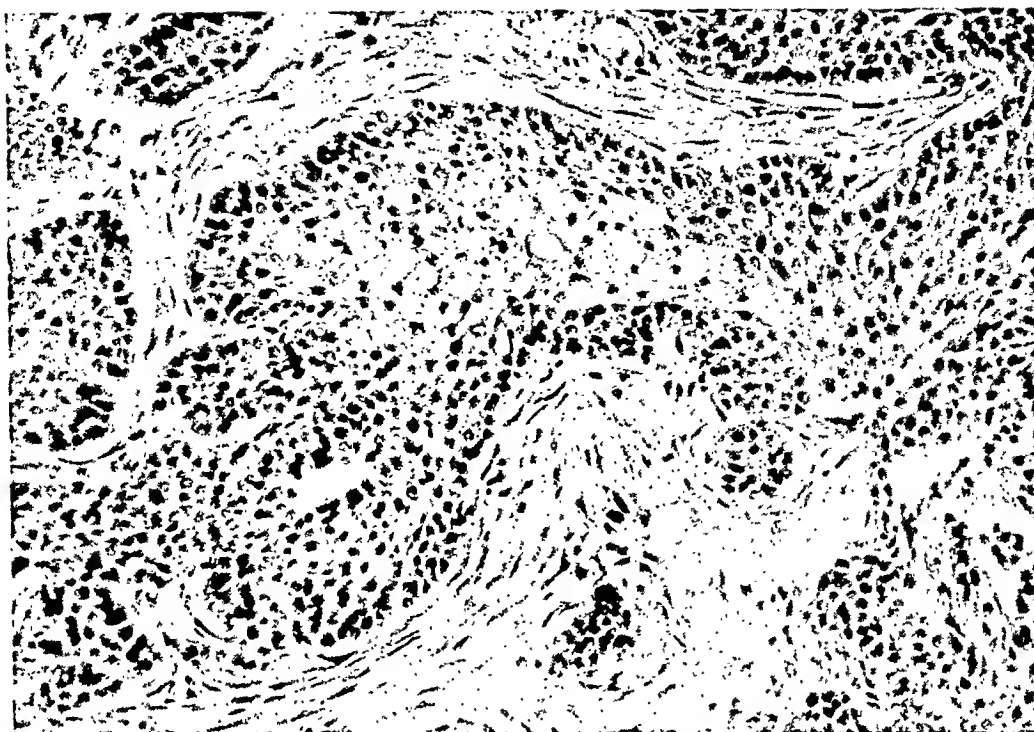


FIG. 16

FIG. 15.—Malignant muco-epidermoid tumor of tongue. Basal and intermediate cells merging with mucous cells; the latter stained intensely with mucicarmine. (See also Figures 16 and 17)

FIG. 16.—Metastasis to subcutaneous tissue of scalp from tumor in Figure 15. Cells exhibit squamous and epidermoid characters.

FIG. 17

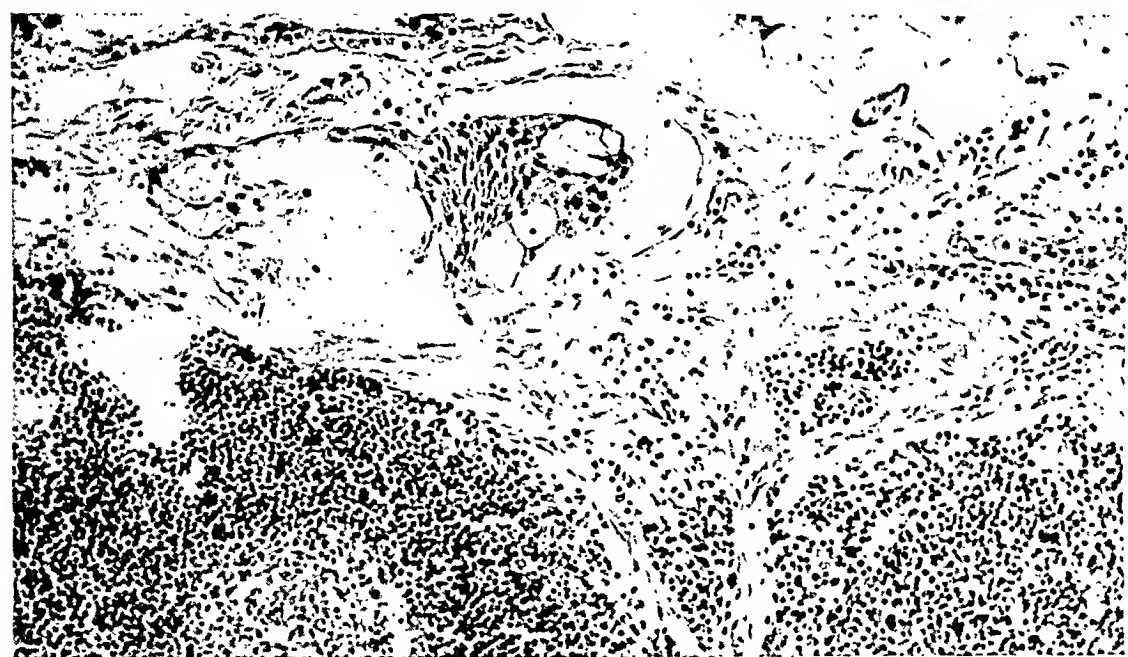
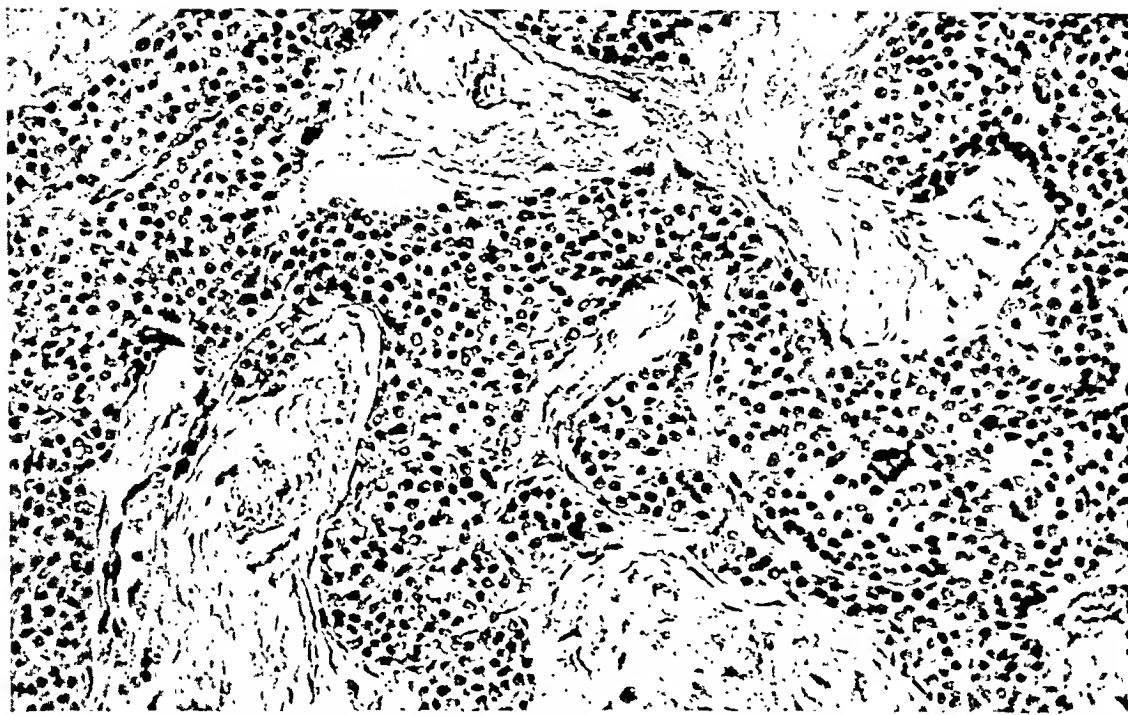


FIG. 18

FIG. 17.—Another area of the metastatic nodule seen in Figure 16. Intermediate cells.

FIG. 18.—Embolus in afferent lymphatic from malignant parotid salivary gland tumor. Several mucous cells are included.



It was possible to demonstrate mucous cells in large numbers in the metastases of four tumors and in moderate number in a fifth. In this connection Figure 4 may be consulted.

#### GROSS PATHOLOGY OF THE BENIGN TUMORS

Observations here are based on findings in 14 primary and nine recurrent tumors. As a rule they did not reach large dimensions. The largest tumors measured 4 cm. in greatest diameter. One was a centimeter in diameter and the smallest measured only 4 mm. The majority ranged from 2 to 3 cm. in greatest dimension. Regardless of location they tended to be ovoid in shape. Usually they were fairly well circumscribed but a well-developed capsule was present in only four of the 26 benign tumors. Poor encapsulation was the general rule and four were unencapsulated. The foregoing gross qualities were evident regardless of whether the tumors were primary or recurrent. Of some importance was the finding that some of those tumors which appeared rather well encapsulated in the gross did not show such sharp delimitation in microscopic sections. The lack of encapsulation in an occasional case was impressive and was further complicated by abundant mucoid secretion with leakage into adjacent tissue spaces. Extensive, locally infiltrative growth followed in a manner somewhat reminiscent of the local spread of some colloid carcinomas.

Before sectioning, most of the benign tumors were moderately firm but in most instances lacked extreme induration. The degree of firmness, however, differed widely among those tumors that were variously cystic or solid. On cut section the majority, were at least partially cystic, the cystic spaces usually being multiple and from two to three millimeters in diameter. There were extreme examples where very large cystic cavities, one or more in number, comprised the bulk of the tumor. Some of the tumors were solid in one or more areas, unicystic or multicystic in others. Still others showed no gross cyst formation. The cystic spaces invariably contained nearly clear, opalescent or blood-stained mucoid material usually moderately viscid but sometimes thin. In tumors that were principally solid, lobulation was seldom seen and the cut surfaces were usually grayish-white or grayish-pink. In about half of the tumors there was discoloration due to secondary hemorrhage and/or necrosis.

#### GROSS PATHOLOGY OF THE MALIGNANT TUMORS

Of the 19 malignant tumors there were nine in which no surgical excisions were done and, hence, only ten gross specimens were available for study. Of these, four were primary and six recurrent. Here, as in the benign tumors, large bulk was not a pronounced characteristic since the largest tumor was 5 cm. in diameter and the majority were 2 to 3 cm. in greatest dimension. Lack of encapsulation was a distinct feature. Ordinarily they were obviously infiltrative and only a few were circumscribed. When compared with the benign tumors there was much less tendency towards cyst formation. Two tumors were grossly cystic but this was obviously the result of necrosis.

None of the ten tumors showed grossly visible mucus aggregates. They were distinctly firm, cellular, opaque, gray-white and homogeneous. Hemorrhage and necrosis were fairly common.

#### CLINICAL ASPECTS

Sex was not a factor in muco-epidermoid tumors since both the benign and malignant tumors were approximately equally divided between males and females.

The factor of age is represented in Table I from two points of view, namely, the age of the patients at the onset of the first symptom and the age when first seen at Memorial Hospital. (Ages are recorded in years according to the nearest birthday.)

TABLE I

Benign Tumors			Malignant Tumors		
Case No.	Age at Onset of First Symptom	Age When First Seen at Memorial Hospital	Case No.	Age at Onset of First Symptom	Age When First Seen at Memorial Hospital
2	16	17	1	34	36
3	38	39	4	69	70
5	42	43	8	64	66
6	21	22	9	25	50
7	39	40	11	74	75
10	26	28	14	36	44
12	56	59	16	11	12
13	54	57	22	35	36
15	54	59	23	49	54
17	7	8	30	?	18
18	56	56	32	63	63
19	43	44	33	59	60
20	31	36	34	62	64
21	38	40	36	52	54
24	23	26	38	56	57
25	41	43	39	43	44
26	24	25	40	48	49
27	20	21	41	13½	16
28	48	49	42	55	61
29	34	39			
31	22	28			
35	23	48			
37	34	35			
43	59	60			
44	41	42			
45	42	45			

From Table I it is evident that there is a general trend for the benign tumors to occur in a younger age group. Thus, when based on the age of patients at the onset of the first symptom, 42 per cent of the benign tumors occurred in patients over 40 years of age, whereas, 65 per cent of malignant tumors were in patients older than this. Similarly, only 25 per cent of benign tumors occurred in people over 50 years of age, whereas, approximately 50 per cent of malignant tumors were in patients 50 or more years old. The youngest patient was seven and one-half years old at the onset of the first symptom. This tumor was benign and arose in the parotid salivary gland. The youngest patient with a malignant tumor was 11 years old, and this tumor was also of parotid origin. No case among the benign tumors was

as much as 60 years of age when symptoms began, whereas, about one-fourth of the malignant tumors first gave symptoms after the patient was at least 60 years of age.

### LOCATION

The distribution of both benign and malignant muco-epidermoid tumors is shown in Table II:

TABLE II

LOCATION OF FORTY-FIVE MUCO-EPIDERMOID SALIVARY GLAND TUMORS

	Benign	Malignant
Parotid salivary gland.....	20	7
Submaxillary salivary gland.....	1	2
Sublingual salivary gland.....	0	1
Minor salivary glands (including mucous glands of nasal cavity):		
a. Mucosa of cheek.....	1	
b. Mucosa of hard palate.....	1	
c. Mucosa of faucial tonsil.....	1	1
d. Mucosa of nasal cavity.....	1	3
e. Mucosa of tongue.....	1	2
f. Mucosa of alveolar ridge.....		2
g. Mucosa of nasopharynx.....		1

Table II shows that the parotid salivary glands were distinctly the most common sites of both the benign and malignant muco-epidermoid tumors. The bulk of these tumors was benign. Other major salivary glands were only exceptionally involved. Nearly one-third of the tumors arose from minor salivary glands in a variety of locations. It is noteworthy that most of these tumors were malignant. Thus, the general anatomic distribution of muco-epidermoid tumors is largely similar to that of other classes of salivary gland tumors.

### SYMPTOMATOLOGY

*Benign Tumors:* Outstanding as an initial symptom in the benign tumors was painless swelling. This was true in 22 (85 per cent) of the 26 benign lesions. The first symptom in one case in which the tumor arose in the hard palate was pain after eating. In another case continuous throbbing pain developed in the region of the parotid salivary gland. Two of the benign tumors were discovered accidentally during the course of routine physical examination. Local pain developed at some subsequent date in about one-fourth of the benign tumors. A later development in one case was the appearance of bloody saliva. In none of the benign lesions was there any presenting symptom related to facial nerve involvement. In almost all of the benign tumors the rate of growth under observation, or as related by the patient, was described as quite slow or apparently stationary. In none of these cases was impressively rapid growth recorded.

Fifteen of the 26 patients with benign tumors had not been treated prior to admission at Memorial Hospital and the duration of symptoms in these cases was accurately recorded. There was wide fluctuation. Nine had had one or more symptoms for a year, or more. In six of these nine, more than



two years had elapsed since symptoms began and in two patients the tumors had been known to be present for at least five years.

*Malignant Tumors:* The symptom complex observed in the 19 patients with malignant tumors was far more varied than that observed in patients with benign tumors. The principal reason for this depended largely upon their location within the oral or nasal cavity. Another factor was their more aggressive growth. In eight (42 per cent) of the 19 cases painless swelling was the initial symptom. This is in contrast to the presence of a painless swelling in 85 per cent of the benign tumors. Three patients first noticed painful swelling. Other initial symptoms included local pain without knowledge of the existence of a mass, lacrimation, nosebleed, and nasal discharge. In one patient the presence of tumor was first disclosed when his wife noted a lump in his neck. On investigation this proved to be a metastasis from a tumor primary in the tonsillar region. Other symptoms that occurred during some phase of the disease before medical advice was sought included numbness of one side of the tongue, interference with speech, dryness of the mouth, and sore throat. One patient first noted a painless mass which soon became painful. Lacrimation, trismus, and evidence of weakness of the facial nerve followed in the order given. In the benign tumors pain was by no means a clinical feature, whereas, this symptom was present in most of the malignant tumors before a physician was consulted. The rate of growth in the malignant tumors was described as rapid in about half of the cases. In the remaining cases it was reported as slow and in one was regarded as stationary. In the occasional case one was impressed by a history of recent, rapid enlargement of a tumor which had been quiescent or nearly static for several or many years. None of the patients with benign tumors gave a history of cachexia and weight loss, but this had occurred in three patients with malignant tumors.

Ten of the 19 cases had not been treated prior to examination at Memorial Hospital. In these the duration of symptoms was specifically stated. In six, symptoms had been present for less than one year, usually a short space of months. In four, the duration of symptoms was a year or longer. Included among the latter was a patient with a tumor of the hard palate known to have been present for 25 years. There was a history of rapid enlargement for six weeks during which the overlying mucosa had become ulcerated. On examination a firm cervical lymph node was thought to contain metastatic tumor. Of more than passing interest was the finding that much of the tumor was histologically benign (Fig. 14) but other portions showed the structure of epidermoid carcinoma (Fig. 13). The patient died within a year, after having developed abdominal distress and a large, nodular liver. Another case with similar implications concerned a parotid tumor of six years' known duration with slow enlargement. Growth was described as very rapid for eight months and during this time function of the facial nerve became partially impaired. Radical excision of the parotid salivary gland and tumor combined with radical neck dissection was done. The

primary tumor contained areas that were both benign and malignant in structure and there was metastasis to a single cervical lymph node. These two cases have been briefly presented as evidence of the transformation of benign into malignant tumors.

#### LOCAL FINDINGS ON FIRST EXAMINATION AT MEMORIAL HOSPITAL

*Benign Tumors:* The local findings did not differ significantly whether the tumors were or were not recurrent. Those tumors of major salivary glands (20 parotid, one submaxillary) were almost invariably described as firm or moderately firm on palpation. An occasional tumor was regarded as elastic or rubbery. Only two were considered cystic and, hence, this property was much more apparent pathologically than clinically. Whereas, most of the tumors had rather well defined limits on palpation, precise outline was much less common than observed in so-called mixed tumors. As would be expected, the clinical estimation of size in centimeters was greater than that actually found on pathologic examination. The tumors did not center in any particular area of the parotid salivary gland. Five of the 20 benign parotid tumors seemed definitely fixed and several others were not easily movable. One tumor which was recurrent infiltrated skin extensively and caused central ulceration. Another tumor, not recurrent, had also extended into and became fixed to overlying skin, without, however, causing ulceration. Another case presented a recurrent tumor described as fixed and infiltrating skin. Noteworthy, here, was the breakdown of skin and the discharge of large quantities of mucoïd material. None of the primary parotid tumors presented any but a single mass but in two recurrent cases there were multiple discrete tumor nodules. No disturbance in the function of the seventh nerve was found except in one case where the nerve had been damaged at a previous operation. The single benign tumor involving the submaxillary salivary gland gave no unique local findings.

The five benign tumors of minor salivary gland origin were submucosal in location with one exception, a polypoid tumor of the nasal cavity. This tumor was also polypoid when it recurred. The other tumors were variously rounded and irregular, firm or moderately firm and more or less fixed. The overlying mucosa was elevated in all cases and in two cases was ulcerated. Neither of these tumors was recurrent. The regional distribution of the benign tumors of minor salivary gland origin is shown in Table II.

*Malignant Tumors:* Regardless of whether the malignant tumors were primary, recurrent, or of major or minor salivary gland origin, they were with little exception firm, fixed, poorly circumscribed and infiltrative. One of the submaxillary gland tumors was felt to be partly cystic. Both of the submaxillary tumors had fungated through skin. The growth of one parotid tumor interfered with the function of branches of the facial nerve. In this case there had been no previous treatment, the tumor had been slowly enlarging for six years but had exhibited rapid growth for eight months. Mucosal ulceration was present in all but two cases of minor

salivary gland origin. Further local complications caused by intraoral and intranasal tumors were erosion and penetration of adjacent bony structures.

#### RECURRENCE AND METASTASIS

*Patients with Benign Tumors:* Eleven of the 26 cases in this group had tumors recurrent after surgery when first seen at Memorial Hospital, and three of these 11 were twice recurrent. The time-interval between excision and the recognition of recurrence varied greatly. Precise dates were recorded in nine cases and were nine years, five years, two years, ten months (two cases), three months, two months (two cases), and one month. Thus, as in other types of salivary gland tumors late recurrence may be a clinical characteristic. Ten of the recurrent tumors were of parotid origin and the other arose in the nasal cavity. The latter tumor had been discovered on routine physical examination and had been excised under the clinical diagnosis of nasal polypus.

*Patients with Malignant Tumors:* Of 19 such cases nine were recurrent after surgery when first seen at Memorial Hospital. Five of the nine recurrent cases had had more than one reexcision for recurrent tumor. The time-interval between operation and clinical recurrence was characteristically a short space of months but in a single case there was a lapse of seven years. It is, thus, apparent that rapid recurrence is far more likely in the malignant than the benign muco-epidermoid tumors.

On initial examination ten patients had clinical evidence of metastasis. This was confirmed pathologically in eight. The metastatic lesions involved cervical lymph nodes in all but one instance. In this the supraclavicular nodes contained secondary deposits from a tumor primary in the submaxillary salivary gland. Four of the primary tumors arose in major and six in minor salivary glands of the oral cavity. In six of the ten cases presenting with metastatic lesions there had been no previous treatment.

The material available afforded relatively little opportunity to study the distribution of distant metastases. There were only two autopsies and in one metastases were limited to cervical nodes. In the other there were extensive generalized metastases including regional, mediastinal, para-aortic and iliac lymph nodes, lungs, pleurae, myocardium, liver, and subcutaneous tissue. The primary tumor was located on the alveolar ridge. In another case there was clinical evidence of metastases to the liver. With some surprise it was found that in three cases (including the above mentioned case with autopsy) distant subcutaneous metastases developed. Regions involved included the face, scalp, axilla, and abdomen and in each case positive excisional biopsies were secured (Fig. 4).

#### RESULTS OF TREATMENT

*Benign Tumors:* In 14 cases more than five years have elapsed since the beginning of treatment at Memorial Hospital. Three of these were lost to follow-up and were free of disease less than one year, two and two and one-half years when lost. Nine cases were alive and free from disease and

two cases had developed recurrent tumors, one definitely inoperable, the other probably inoperable.

Two of the nine five-year cures were accomplished by irradiation measures alone. One of these cases was that of a parotid tumor recurrent after surgical excision. It measured 5 x 3 cm. in greatest dimensions. The insertion of gold-filtered radon seeds, totalling 25 millicuries destroyed, was followed by complete regression. The other case cured by irradiation alone presented a previously untreated 3-cm. tumor of the mucosa of the cheek situated posteriorly between the upper and lower alveolus. Between June 18 and 26, 1934, the patient received 2000 r of 200 K. V. roentgen ray through a 7-cm. field in single fractions of 250 r, 0.5 mm. copper filtration, target-skin distance 63 cm. One month after the completion of this cycle there was moderate regression and at this time gold seeds, totalling 22.4 millicuries destroyed, were inserted into the tumor. Gradual, complete regression followed.

Of the seven remaining five-year cures, three had surgical excision alone. All of these were parotid tumors, two were previously untreated and one was recurrent two years after surgical excision. None recurred after treatment at Memorial Hospital.

Four of the nine cases cured for five years, or more, received combined surgical and radiation treatment. None of these tumors recurred after treatment. Three of these tumors were of parotid and one of submaxillary salivary gland origin. In each of these four cases gold seeds were implanted at the time of operation in the area from which the tumor had been excised. The amount of radon seed implantation was not uniform, and was recorded as 9, 10, 23.6, and 29.9 millicuries destroyed. One of these four cases received in addition to the interstitial irradiation, 48,000 milligram-hours with the four gram radium element pack in daily fractions of 4,000 milligram-hours. In these cases treated by combined surgery and irradiation it is impossible to evaluate the rôle of irradiation in cure.

There was not sufficient material among the benign tumors to estimate the effect of external irradiation. In only one case was this form of therapy employed in appreciable amount. This was a case of nonrecurrent parotid tumor which was surgically excised and treated postoperatively with 220 K. V. roentgen ray through a 4-cm. cone, in daily fractions of 200 and 300 r, 0.5 mm. copper filtration, target-skin distance 50 cm., for a total of 4900 r. This tumor recurred in less than a year.

*Malignant Tumors:* The highly fatal character of this group can be shown by briefly enumerating facts concerning those patients known to be dead or alive. Seven are dead. The duration of life after treatment was undertaken at Memorial Hospital was two, three, five, eight, and nine months, two and ten years. The last patient succumbed to both locally recurrent and metastatic tumor as shown by biopsy after having been free from evidence of disease for five years. Five of the seven fatal cases had clinical or pathologic evidence of metastases (usually cervical node) when treatment was begun. Twelve patients are living, but two of these are dying

with locally uncontrolled tumor and a third is known to have subcutaneous metastases. One patient, alone, is alive and free from evidence of tumor for more than five years. Two patients are living three and one-half and two years, respectively, following therapy, and are believed free from disease. The first of these cases was a recurrent parotid tumor without metastases and surgical excision was the only treatment. The second was a primary tonsillar tumor with cervical node metastases treated with external and interstitial irradiation. The follow-up period in the remaining eight cases still living is too short for significant comment.

The purpose in presenting the preceding data on the results of treatment has been to establish the contrasting clinical behavior of the tumors variously classified as benign and malignant. It is inappropriate, and beyond the capabilities of pathologists, to decide on methods of treatment in a class of tumors presenting so many complexities related to specialized regional surgery and the application of various forms of irradiation therapy.

#### SUMMARY

A little recognized group of salivary gland tumors has been presented and the term, "muco-epidermoid" tumor, applied to them. Reasons have been advanced implicating the salivary gland ducts as their anatomic site of origin. These tumors are believed to represent a specific pathologic type distinct from generally accepted varieties of salivary gland tumors. The 45 tumors included herein have been separated into two groups, benign and malignant, as qualified in the text. Their pathologic aspects have been discussed in full and these have been correlated with clinical behavior.

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## REGIONAL ENTERITIS

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THE LITERATURE relating to regional enteritis has become rather voluminous during the past 13 years. Scarcely an article has been written in which the author has not in the first column (frequently in the first paragraph), referred to the original article by Crohn, Ginzburg and Oppenheimer,<sup>1</sup> which appeared in the Journal of the American Medical Association, October 15, 1932. That paper first describing this clinical entity as a disease *sui generis* was read before the Section on Gastro-enterology and Proctology at the 83rd session of the American Medical Association, New Orleans, Louisiana, May 13, 1932. It was a remarkable treatise not merely because it raised the curtain on an hitherto unheralded disease but chiefly because of the accuracy and fullness of the observations on the part of the authors and the intelligent and intelligible recording of those observations by them.

In fact, so accurate was the original Crohn, Ginzberg, Oppenheimer story of regional enteritis that in all the literature contributed to the subject during the years that have followed, nothing has been subtracted from it. And so today, one may say to a medical student or intern: "If you would acquire sufficient knowledge of this condition to recognize and know how to treat it, all you need do is read the original article."

The original title of terminal ileitis was changed following the suggestion of Dr. Bargen that the word "terminal" suggested agonal, and regional was substituted therefor. Enteritis has been substituted for "ileitis" since it has subsequently been demonstrated, time and again, that any part of either the large or small bowel and not infrequently a part of both in the same patient may be involved, although the ileum and indeed the terminal ileum is the overwhelmingly favorite site. In 87 per cent of the cases reported by Dixon<sup>2</sup> the disease was confined to the terminal ileum. A great variety of names have been offered as a designation for this condition by the numerous contributors to the subject, among which have been, in addition to the original of terminal ileitis, regional ileitis, regional ileocolitis, regional enterocolitis, segmental enteritis, nonspecific granuloma, infective granuloma, chronic cicatrizing enteritis, pseudocancer, Crohn's disease, and, finally, regional enteritis. The latter term is the most popular and comes nearest to being true and the most appropriate.

Whenever a new idea is evolved or discovery made, the literature is sure to be flooded with a great many offerings related to the original. In some, one thing is emphasized; in some, another. Preliminary to the preparation of this paper, 39 articles by different authors which have appeared in a wide

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assortment of medical and surgical journals of this country, Canada, and the British Isles were reviewed by the author. Our series of 17 cases illustrates a variety of the special features which have been pointed out and have been made the central theme for various of these individual articles. It is for the purpose not only of adding our series of cases to the literature but, moreover, for the purpose of adding confirmation to the several special observations which have been made by a variety of contributors and which are borne out by our experience that this report is being made.

*Historical:* While all credit is due the original authors, above referred to, for their astuteness and perspicacity leading them to make their epochal report, it is not believed that this was really a new disease. There are numerous reports in the literature indicating that it has existed for centuries. In 1913, Combe, of England (Phillips<sup>3</sup>) described a case of thickening and stricture of the ileum at postmortem. This in all probability was a case of regional enteritis. Moschcowitz (Phillips<sup>3</sup>) reported a small series in 1923, which may well have been cases of regional enteritis; and, in 1893, W. J. Mayo<sup>4</sup> described what he termed granuloma of the small intestine. The writer recalls very clearly having witnessed an operation when he was a medical student in the early '20's in which an involvement of the ileum, typical of segmental enteritis, was demonstrated and was thought to be of tuberculous origin. Subsequent to that time, and prior to 1932, he saw several similar cases.

That the incidence is increasing is indicated by a report from the Mayo Clinic, by Donald and Brown,<sup>5</sup> in 1941. They reported 178 cases at the clinic between the years 1922 and 1940, and 114 cases between 1937 and 1941. More convincing evidence of the increase in the incidence of the disease is offered by Fallis,<sup>6</sup> who reports only one case of granuloma of the small bowel and seven cases of tuberculosis of the small intestine in 195,000 patients admitted to the Henry Ford Hospital, Detroit, during a 15-year period prior to January 1, 1933. During the ensuing ten-year period, that is, from 1933 to 1943, out of 180,000 new patients, there were 27 positively proven cases of regional enteritis, and five additional cases diagnosed on the interpretation of the history and roentgenographic findings—making a total of 32 cases. While sharper recognition is admitted as a possible factor, it is not regarded as the sole explanation for this apparent increase in incidence.

*Etiology:* As has been said of Banti's disease, and as is true of chronic ulcerative colitis and a number of constitutional disorders, a lack of knowledge as to the etiology seems essential to a diagnosis of regional enteritis. A number of theories have been advanced—some have been disproven, some remain purely nebulous. Of the disproven theories, that purporting to assign to Koch's bacillus of either the human, bovine, or avian variety the rôle of causative agent heads the list.

That allergy may in some manner tie in with this disease entity remains in the category of fancy. That there is a correlation between mesenteric lymphadenitis and regional enteritis seems not improbable, but which is the cause and which the effect remains a moot question. Several writers,

notably Donald and Brown,<sup>5</sup> have suggested that the malady has a predilection for Jews, particularly at an early age. It has been claimed that the disease is more common in the Eastern cities. This appears to be borne out by case reports in the literature, however, the validity of this claim may be more apparent than real when we consider that there are more people in the Eastern states, and particular interest in this condition has been manifested by Eastern writers. In our series of 17 cases only one, the first, was a Jew. The group comprised personnel of the U. S. Navy admitted over a two-year period to the U. S. Naval Hospital, San Diego, California. There were 15 enlisted men and two officers. The fact that they were near southern California at the time of their transfer to the hospital by no means indicates that they were anywhere near that part of the world at the time of the original onset of their disease. Actually, from their histories, it would appear that not more than one of the entire group developed his disease in California. That there is a seasonal variation in the incidence of this disease or at least in the tendency towards an acute exacerbation of the pathologic process appears quite probable and is to some extent borne out by our experience. That a familial tendency may play a rôle in the occurrence of regional enteritis has been suggested by Crohn.<sup>7</sup> That the disease is distinctly more prone to appear between the ages of 15 and 40 seems to be generally recognized. The youngest in our series was 17, the oldest 33. The majority of the statistical reports indicate that the disease has a preference for males in a ratio of 3 to 2 (Crohn<sup>7</sup>), Fallis<sup>6</sup> found this ratio to be 4 to 3. However, Marshall,<sup>8</sup> at the Lahey Clinic, reported 13 men and 16 women in a series of 29 cases. All 17 of our cases were males.

*Pathogenesis:* The earliest or incipient stage of regional enteritis remains more or less conjectural, since it is seldom, if ever, recognized at operation or roentgenographically until at least a fairly advanced or well-defined stage has been reached. It seems reasonable, however, to surmise that it begins as a proliferative process in the interstitial structure of the bowel wall and gradually assumes the characteristics of a cicatrizing granulomatous lesion. Hence the term "pseudocancer." As the wall of the bowel becomes thickened, the mucosa becomes ulcerated, possibly due to interference with the blood supply and possibly due to an infective process, either virus or bacterial in character. Whether the fibrosis is secondary to the ulcerative process or the ulcerative process is secondary to the fibrosis is not known. In any event, as the disease progresses, the bowel wall becomes progressively thicker and as a result of this change, plus the contraction of cicatrizing ulcerated areas, the lumen is encroached upon and thus narrowed, until obstruction eventuates in some cases.

While the bowel is undergoing these changes, the adjacent mesentery becomes thickened and the mesenteric lymph nodes become enlarged but usually remain discrete. An edematous condition is superimposed in the bowel structure and mesentery alike. As this pathologic action advances, the ulcerated areas tend to perforate, leading to abscess and fistula formation. These



fistulae may communicate internally with adherent loops of small bowel, large bowel, or bladder, or externally with the surface through the abdominal wall or any combination of these possibilities may obtain. The premises upon which some writers upon this subject have based their reasoning that this disease may progress through four more or less well-defined stages, namely: First, acute; second, irritative; third, obstructive; and fourth, fistulae, are, therefore, readily understood.

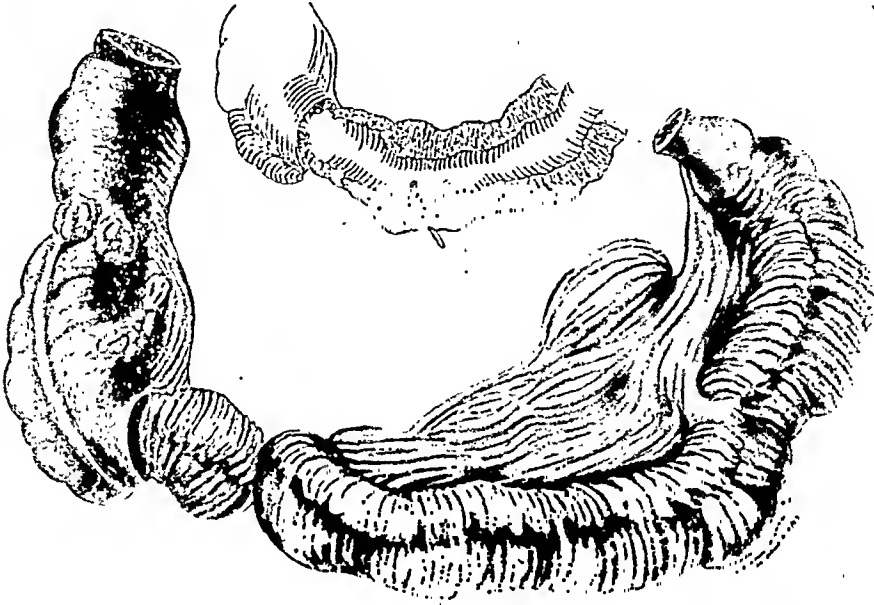


FIG. 1.—Drawing of segment of involved ileum showing the classical corrugated or cobblestone appearance of the bowel and its adjacent mesentery. Note sharp line of demarcation at ileocecal junction. Thickening of bowel wall, narrowing of lumen, and presence of fistula are shown in the insert. The findings upon roentgenologic examination in this case are shown in Figures 3 and 4.

There is also a wide range of possibilities as to the extent and part of the intestinal tract that may be involved. While, as has been pointed out, the terminal ileum *per se* is overwhelmingly the favorite site for involvement, nevertheless, the disease extends past the ileocecal junction and invades the cecum in an appreciable number of cases (Figs. 7 and 9). Likewise, may any part of the bowel, from the jejunum to the sigmoid, be affected. Moreover, several portions of the bowel may be involved in the same patient, with healthy segments intervening, hence, what is referred to by various writers as “skipped areas” are demonstrable.

The disease is chronic in its course, and is characterized by periods of exacerbation and remission. The duration of these phases appears to vary with different individuals and, undoubtedly, is in some measure influenced by the physical stamina and general health of the individual. In any event, the weight of evidence and opinion indicates that spontaneous cure, if it ever occurs, is rare. This view is probably somewhat radical. Appreciable contradictory evidence is not lacking. (Our Cases 10, 12, and 16.)

There is a marked contrast between the appearance of the bowel during an acute and a quiescent or remission stage. In the acute phase, the involved surface is swollen, inflamed and hyperemic. Its surface may be coated with a plastic exudate. The mesentery is likewise swollen, edematous and inflamed, and its contained lymph nodes may constitute tumor masses varying in size from that of a pea to that of an English walnut (Fig. 9). Gross corrugations

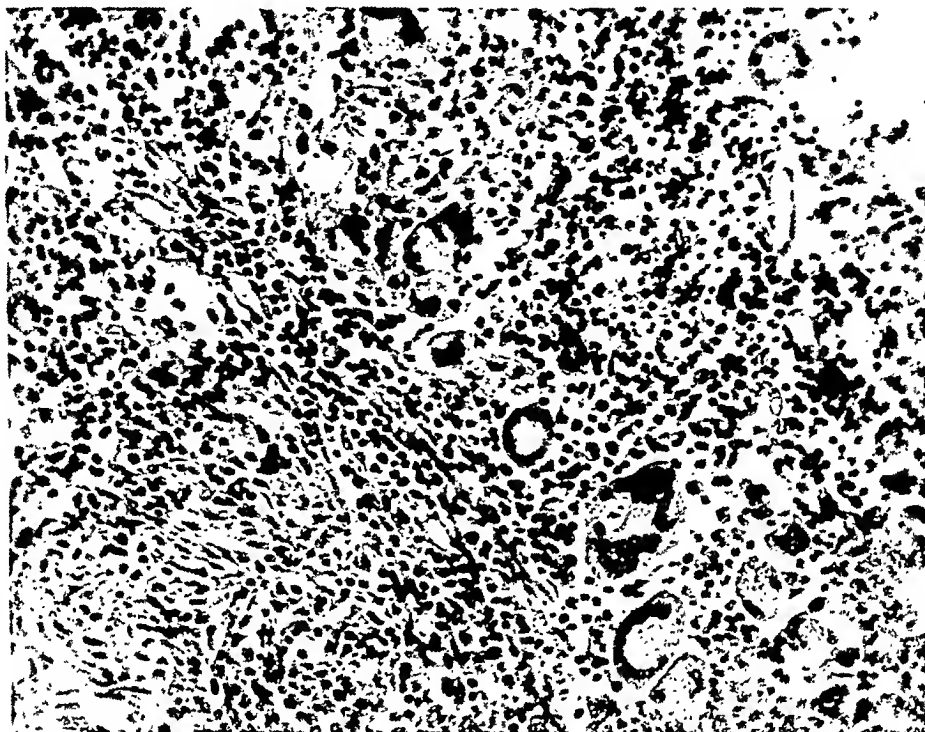


FIG. 2.—Microscopic appearance of tissue removed from the gross specimen shown in Figure 7. It was upon the presence of giant cells, such as are shown in this section, that the theory of tuberculosis as an etiologic factor was predicated.

which extend from the mesenteric border and tend to encircle the bowel become more prominent as the disease persists, and during an acute episode these markings are greatly accentuated. This has been described by Sneierson and Ryan<sup>9</sup> as a "cobblestone" appearance (Figs. 1 and 9).

A considerable accumulation of serosanguineous fluid within the peritoneal cavity is not uncommon during the acute phase. During quiescence or remission from acute activity, the bowel remains thickened, heavy and leathery in consistency, and is devoid of its normal flexibility and distendability. As the hyperemia subsides, organization of the plastic exudate laid down during an acute attack leads to the development of dense fibrous bands and adhesions during the remission phase.

In a typical case, histopathologic examination of a segment of bowel affected with regional enteritis reveals a marked fibrosis and thickening of the submucosal and mucosal layers. The entire structure of the bowel wall is apt to show a mononuclear infiltration, with a preponderance of these cells in the mucosal layer. Giant cells (Fig. 2) are also commonly seen and have

been largely responsible for the erroneous assumption that the tubercle bacillus was the mischief maker.

*Symptoms:* The symptoms will, to a very appreciable degree, depend upon the stage, location, and severity of the disease. The three cardinal symptoms of regional enteritis are abdominal pain, intermittent diarrhea, and loss of weight. The latter is not as consistent a finding as the first two. The pain is usually cramp-like, intermittent, and recurrent in character. Nausea is not uncommon and when present vomiting as a concomitant symptom is the rule.

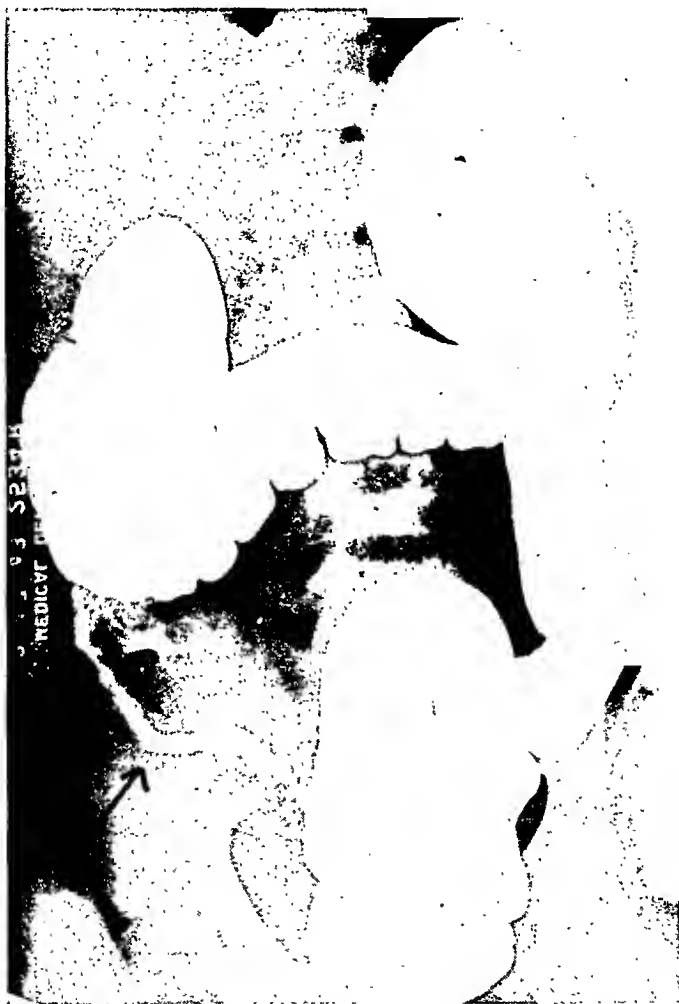


FIG. 3.—Roentgenogram showing narrowing of lumen of ileum. Note amount of barium in large bowel before opaque media could be forced into the ileum.

In some cases the pain, nausea, and vomiting assume such proportions as to lead to a suspicion of intestinal obstruction, although complete obstruction seldom occurs. Anorexia is also experienced in a goodly percentage of cases. The onset may be sudden and the patient may fail to give a history of antecedent prodromal symptoms. The pain is apt to be most severe in the right lower quadrant and, therefore, the fact that over 50 per cent of the patients in our series, as is true of most of the series reported, have been erroneously

## REGIONAL ENTERITIS

diagnosed as acute appendicitis, and have been operated upon for that condition, is quite naturally accounted for. Hemorrhage from the bowel, while not usually regarded as an evidence of regional enteritis, does occasionally occur in this condition and in the absence of a more readily demonstrable explanation should be considered as a diagnostic indication of appreciable import.

*Signs:* When coupled with the symptoms as above indicated, anemia is a common sign of regional enteritis. Some elevation of the patient's tempera-



FIG. 4.—Same case as illustrated in Figure 3, after evacuation of barium enema. The segment of bowel removed at operation in this case is illustrated in Figure 1. While the pathologic process did not extend to the cecum originally, it is a notable fact that a recurrence became manifest within a few weeks in this case, and upon recurrence the transverse colon was grossly involved along with a second segment of ileum. This was the only patient in the series of 17 who developed a recurrence within a year postoperatively. Following the second resection, this patient has remained symptom-free for over two years.

ture is also common. During an acute exacerbation the temperature will usually show an elevation of from 102° to 103° F., with some fluctuation. During a remission the temperature may be normal, however, a slight P.M. rise is not unusual. The blood picture will characteristically reveal evidence of a moderate secondary anemia and the white count may fluctuate between

normal and that commonly associated with acute appendicitis, depending upon the phase, whether acute or quiescent. Actually, during an acute stage, the white count may be elevated to 18,000 to 20,000 and, therefore, raise a doubt as to the diagnosis of acute appendicitis. The blood sedimentation rate is, as a rule, sharply accentuated during an acute attack.

Abdominal examination will not infrequently reveal the presence of a boggy mass in the right lower quadrant, particularly in thin individuals or when complete relaxation of the abdominal wall is obtained. A mass, along



FIG. 5.—Kantor's string sign.

with tenderness in the right fossa, may also be palpated upon rectal examination. Evidence of ascites is not rare.

Roentgenologic examination is repeatedly referred to as the most important diagnostic aid. Roentgenograms following the ingestion of barium by mouth or when introduced as an enema may reveal the presence of intestinal fistulae at any part of the intestinal tract. However, the classical roentgenographic sign is that produced by a narrowing of the luminal shadow in the terminal ileum (Figs. 3, 4, 5, and 6). This is known as Kantor's<sup>10</sup> string sign, and is excellently described by him in the J.A.M.A., 1934. When present, this sign is considered practically pathognomonic of regional enteritis of the terminal ileum.

*Differential Diagnosis:* The condition with which regional enteritis is most commonly confused is acute appendicitis. A careful history, with emphasis upon prodromal symptoms, is of prime importance. The onset of acute appendicitis is ordinarily more sudden, the point of maximum abdominal tenderness in appendicitis is likely to be more sharply defined, and rebound tenderness is apt to be less striking in regional enteritis. The abdominal mass, which is not uncommonly demonstrable in regional enteritis, is rare in acute appendicitis unless abscess formation has supervened. The white



FIG. 6.—Kantor's string sign.

blood count tends toward greater elevation in an acute stage of regional enteritis, and a sharp and decided drop in the blood sedimentation rate is more indicative of enteritis. Diarrhea is the rule with regional enteritis, while constipation is the rule with acute appendicitis. Intestinal tuberculosis may simulate regional enteritis. Roentgenologic examination is the most important differential diagnostic aid. Moreover, pulmonary tuberculosis is expected to constitute a concomitant disability when intestinal tuberculosis is present. Again, a decided elevation of the white blood count is against tuberculosis. As has been pointed out by Crile:<sup>11</sup> "It is occasionally impossible, even at the time of operation, for the surgeon to distinguish nonspecific regional from

tuberculous enteritis. But since the treatment of these conditions is essentially the same, the matter of differentiating between the two is not of practical importance." Diverticulitis, due either to inflammatory involvement of Meckel's diverticulum or multiple diverticula of the large bowel may produce symptoms similar to regional enteritis. Here again, roentgenologic examination is a valuable diagnostic aid. Amebiasis may produce a picture which could quite likely be confused with regional enteritis. In amebiasis, however, if diarrhea is present, blood and mucus should be looked for in the stool, and sigmoidoscopic examination will reveal characteristic ulcerations in the lower bowel. If there is no amebic involvement of the lower bowel, the patient will probably not have diarrhea with his amebiasis. Finally, the finding of *Endamoeba histolytica* in the stool is proof positive of amebiasis. Chronic

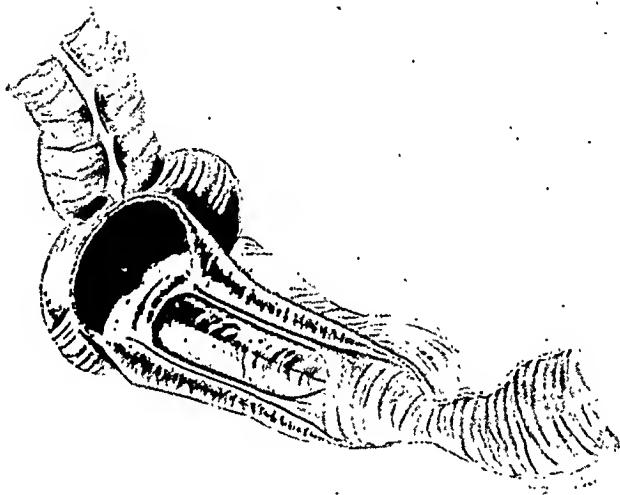


FIG. 7.—Drawing of extension of process beyond ileocecal junction on to cecum. Microscopic appearance of tissue removed from site indicated in this drawing is shown in Figure 2.

ulcerative colitis must be ruled out. In this condition the stools commonly contain blood and much cellular detritus. Sigmoidoscopic examination and roentgenologic examination following barium enema are usually sufficient to rule out or establish the existence of this disease.

*Complications or Sequelae:* Practically every complication, sequela, or peculiarity of this disease which has been described in the literature, and certain of which have been emphasized in particular articles, have been illustrated in one or more of our cases. In order of their frequency in our series of 17 cases, these complications or special features may be listed as follows:

- (1) An involvement of segments of large bowel, apparently as a result of direct extension from involved small bowel segment (Fig. 7).
- (2) Positive Kantor's sign.
- (3) Fistulous communication within the abdomen—internal fistulae.
- (4) Fistulous communication with the abdominal wall—external fistulae.

- (5) Obstruction.
- (6) Skipped areas in the small bowel.
- (7) Apparent subsidence of symptoms and absence of roentgenologic signs without operative interference.
- (8) Hemorrhage.
- (9) Recurrence after operation.
- (10) Fistula or fissure in ano.

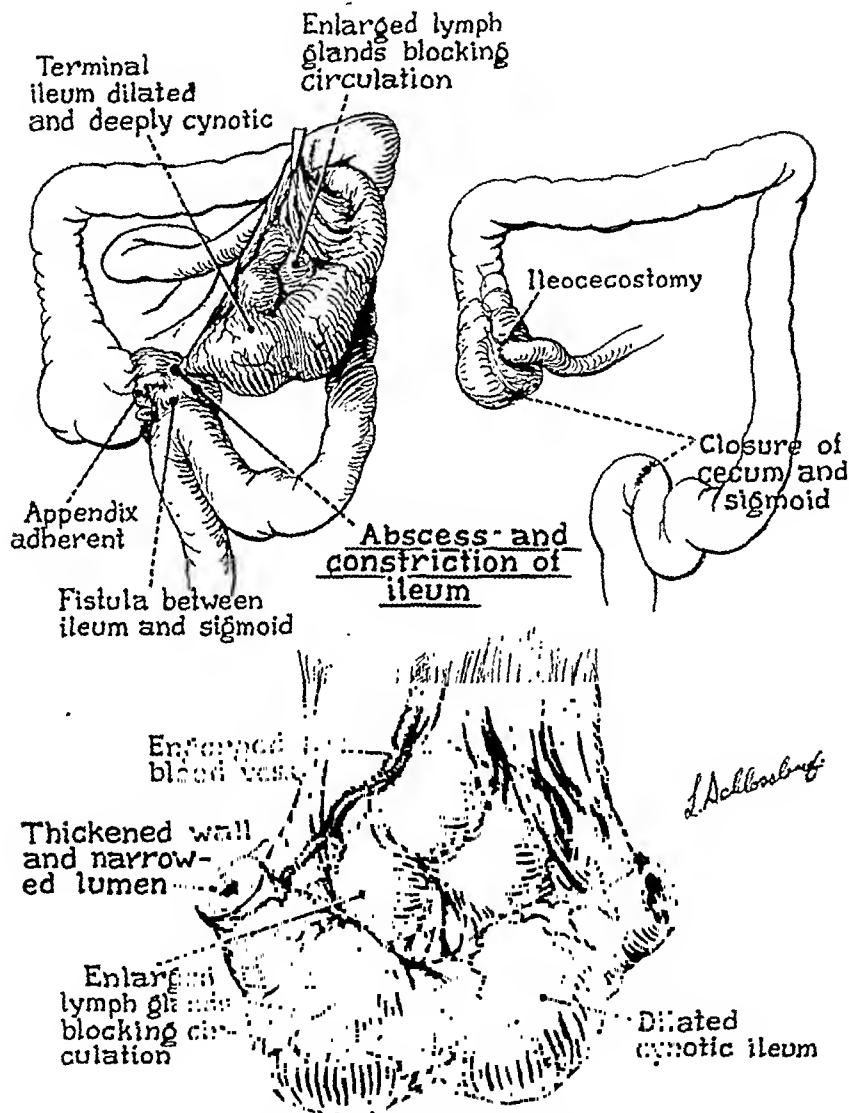


FIG. 8.—Drawing of a markedly dilated, toneless, violaceous loop of ileum, with involvement of sigmoid and fistula formations between the ileum and sigmoid. The disturbance of circulation in this segment of bowel was apparently due to interference with the blood supply by tremendous lymph node enlargement, edema, and fibrotic changes in the mesentery. Resection and closure of sigmoid fistula and end-to-side ileocolostomy was successfully accomplished in a one-stage operation.

In nine cases, over one-half of our series, there was evidence of extension of the pathologic process from the ileum to the large bowel. In six cases the cecum was involved, in two the sigmoid colon, and in one the transverse colon.

Fistulous communication within the abdomen existed in six of our cases. In two there was a fistulous communication between the ileum and



sigmoid colon (Fig. 8). In one there was a fistulous communication between a dependent loop of jejunum and the cecum and a dependent loop of the mid-ileum and the cecum (Fig. 9). In one there was a fistulous communication between the ileum, sigmoid, and urinary bladder (Fig. 10). This complication has been referred to by Bargen.<sup>12</sup> In one there was a fistulous communication between a kink of terminal ileum and the cecum; in another there was a fistulous communication between the ileum and the transverse colon.

Four of our cases developed fistulous communications between the ileum or cecum and the abdominal wall, which extended through to the exterior.

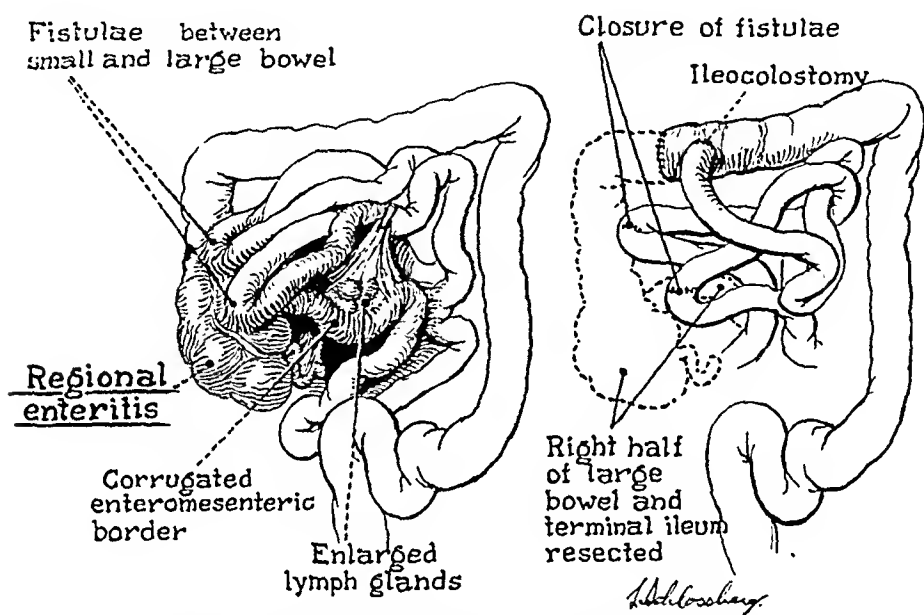


FIG. 9.—Drawing of regional enteritis involving terminal ileum and cecum, with loops of ileum and jejunum adherent to the inflammatory mass, and with communicating fistulae formation between both loops of small bowel and cecum.

In three cases small bowel obstruction constituted the paramount disability and necessitated emergent operative intervention.

Skipped areas in the small bowel were demonstrable in three of our cases.

Fistula in ano was present, or had previously been treated by operation in only one case of our series. Jackman and Smith<sup>13</sup> reported 36, or a 32 per cent incidence, of anal abscess or fistula as a complication of regional enteritis in a series of 114 cases.

In one of our cases, hemorrhage from the bowel had been a notable but not a prominent symptom.

Recurrence necessitating a second operation occurred in one of our cases. At the first operation, two feet of the terminal ileum and the right half of the large bowel were resected (Fig. 1), and an end-to-side ileotransverse colostomy was established. After a month of indifferent improvement or progress following this operation, the patient began to decline markedly. At the second operation the ileum, for a distance of 18 inches, and the transverse colon, for a

# REGIONAL ENTERITIS

distance of ten inches, showed every evidence of a recurrent involvement with regional enteritis. It seems noteworthy that the large bowel was not involved in the original process but became involved when the condition recurred. The diseased bowel was again resected and an end-to-side anastomosis was established between healthy ileum and the colon near the splenic flexure. The patient went on to complete recovery and gained 40 pounds in weight.

TABLE I

REVEALING THE INCIDENCE OF THE MORE COMMON SIGNS AND SYMPTOMS, ALONG WITH OTHER DATA PECULIAR TO REGIONAL ENTERITIS IN A SERIES OF 17 CASES. THIS SERIES IS COMPRISED OF NAVY AND MARINE CORPS PERSONNEL FOUND TO BE AFFECTED WITH REGIONAL ENTERITIS DURING A 27-MONTH PERIOD IN A NAVAL HOSPITAL, WHOSE AVERAGE DAILY PATIENT CENSUS FOR THAT PERIOD WAS 6,268. IT MAY, THEREFORE, BE REGARDED AS A FAIR INDEX OF THE RATE OF OCCURRENCE OF THIS DISEASE IN SERVICE PERSONNEL.

Case No.	Month Admitted	Age	Pain	Diarrhea	Hemorrhage	Loss of Weight	Anemia	Elevated W.B.C.	Diagnosis of Appendicitis	Obstruction	Fissure or Fistula in Ano	Kantor's Sign	Extension to Colon	Internal Fistula	External Fistula	Skipped Areas	Resection	Recurrence	Surgical Cure	Spontaneous Cure?
1	5	24	✓			✓	✓	✓				✓	✓				✓		✓	
2	1	20	✓					✓	✓				✓				✓		✓	
3	1	17	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	
4	2	18	✓				✓	✓	✓				✓		✓		✓		✓	
5	3	21	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	
6	8	24	✓					✓	✓			✓	✓	✓	✓		✓		✓	
7	6	23	✓	✓		✓	✓	✓			✓		✓	✓		✓	✓		✓	
8	11	23	✓					✓	✓				✓				✓		✓	
9	2	21	✓				✓	✓	✓			✓					✓		✓	Died
10	2	19	✓					✓	✓							✓	✓		✓	
11	3	20		✓				✓	✓			✓		✓			✓		✓	✓
12	4	28	✓					✓	✓								✓		✓	✓
13	4	33	✓					✓	✓			✓	✓				✓		✓	
14	6	26	✓	✓		✓		✓	✓	✓		✓	✓	✓			✓		✓	
15	6	18	✓	✓		✓	✓	✓	✓			✓	✓	✓			✓		✓	
16	7	17	✓					✓	✓					✓			✓		✓	
17	6	27	✓	✓		✓	✓	✓	✓			✓					✓		✓	✓
Totals			16	7	1	7	7	17	9	3	1	10	9	6	4	3	14	1	13	3

Three cases in our series cleared up without definitive surgery. The first of these cases was diagnosed as regional enteritis upon his symptoms alone. At operation his jejunum and ileum to within three feet of the ileocecal junction contained at least six areas presenting the classical appearance of regional enteritis with normal bowel of from one to three feet in length in between the diseased segments. Because of the extent and distribution of the involvement, the patient's abdomen was closed without resecting any of the bowel. Penicillin therapy was instituted and the patient rapidly became entirely symptom-free. His bowel was roentgenologically negative. He was sent to duty with the recommendation that he return to the hospital after six months for re-examination. Whether he will remain well and whether or not the penicillin influenced his course is entirely conjectural. One patient had been operated

upon for acute appendicitis aboard ship and what had been described by a seasoned surgeon as a typical regional enteritis involving his terminal ileum was found. He was sent to the hospital for further treatment. Upon second celiotomy five or six months later, scarcely any evidence of a former acute process involving any segment of the intestine could be found. The third case was that of a 19-year-old patient operated upon for acute appendicitis. He was found not to have any appendiceal involvement but his terminal ileum

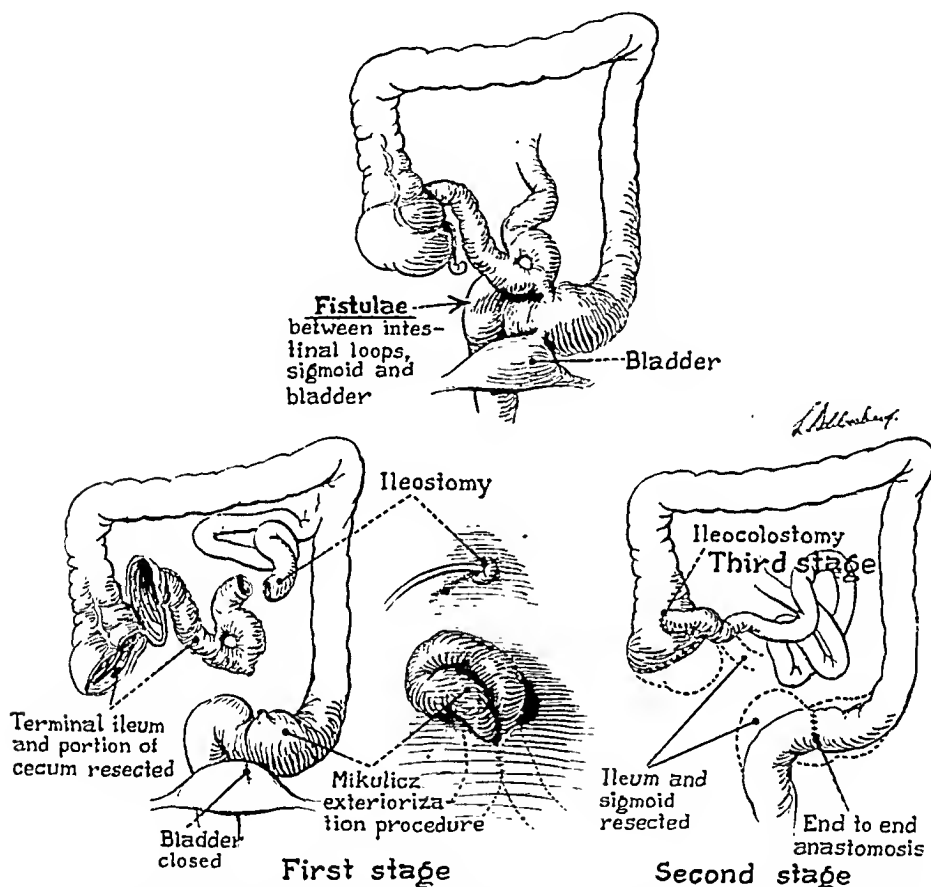


FIG. 10.—Drawing of regional enteritis involving terminal ileum, sigmoid colon, and urinary bladder, with fistulae existing between sigmoid and bladder and sigmoid and ileum. The passage of gas through the urethra was a prominent symptom in this case. The operative procedure involved three steps. First stage: A resection of the involved segments of ileum, closure of fistula in urinary bladder, and the establishment of a temporary single-barrel ileostomy and a double-barrel colostomy. Second stage: While the ileostomy was functioning and the large bowel was functionless, an end-to-end anastomosis was done between the proximal and distal sigmoid segments. Third stage: The ileostomy was taken down and an ileo-ascending colostomy was done, thus restoring complete continuity of the intestinal tract.

was described as typical of regional enteritis. The patient rapidly improved subjectively, however, and roentgenograms revealed no evidence of any departure from normal. Further operation was considered not warranted and the patient was discharged to duty.

*Treatment:* The preponderance of opinion, as expressed in the literature on the subject of regional enteritis, proclaims surgery not only as the treatment of choice but as the treatment of necessity, if a cure is to be hoped

for. There is, however, one notable exception to the disciples of this doctrine. That is Dr. Elliott Cutler,<sup>14</sup> of Harvard University, whose ideas relative to the treatment of regional enteritis appear to be similar to those commonly held with regard to diverticulitis; namely, that the disease is a medical entity unless certain complications such as obstruction, fistulae, or abscess formation arise. Certain of our observations, as borne out by three of our case reports, tend to lend substantiation to Dr. Cutler's contention. Nevertheless, our treatment has been predominantly surgical and it is felt there are ample grounds for the stand that when applied to men in the naval and military service, this form of treatment is by all odds preferable.

Granted that surgery is agreed upon as the accepted means of dealing with regional enteritis, there remains a considerable divergence of opinion as to what constitutes the best surgical procedure. It is unanimously agreed, I believe, that in the presence of an acute process or exacerbation of the disease, it is unwise to institute any form of surgery unless some complication such as obstruction makes emergent intervention imperative. It is, moreover, generally agreed that it is inadvisable to remove a nonentity appendix in the presence of an enteritis of the ileum or cecum, lest a fistula eventuate and that such a fistula will eventuate is well recognized by those who have had appreciable experience with this condition. When then should surgery be performed? It is a dictum of seasoned surgeons that operative measures may be undertaken when the plastic exudate incident to an acute episode has become organized and fibrous adhesions have taken its place.

As to what comprises the most judicious surgical management, it is again agreed that in the presence of obstruction, a short-circulating operation, such as an ileotransverse colostomy, is all that should be undertaken. When the operation may be classed as elective, however, the surgical proponents seem to occupy two fundamental groups: First, those who advocate a two-stage procedure; and second, those who advocate a single-stage operation. Dr. Frank Lahey has formerly stood, and probably still stands, at the head of the two-stage school of thought. A great many at random surgeons advocate a one-stage operation when circumstances will permit. In our series a resection of the involved bowel with an ileocolostomy was done in one stage in all save two of the entire series treated surgically. A preliminary ileotransverse colostomy was done in one case which presented a classical picture of obstruction, and in the case where there was involvement of the sigmoid and fistulous communication with the urinary bladder a three-stage operation was successfully performed. The three stages consisted of, first, a resection of the involved ileum and sigmoid, with establishment of a single-barrel ileostomy; second, an end-to-end anastomosis of the sigmoid, and third, an end-to-side ileo-ascending colostomy.

*Mortality.*—There was one death in our series. A resection of the right half of the large bowel was done in this case, with the establishment of an end-to-side ileotransverse colostomy in one stage. Four days postoperatively this man died of uremia incident to urinary suppression. The cause for the

urinary suppression was never definitely determined, but was attributed to sensitivity to sulfa drugs. There was no demonstrable evidence of blockage of the uriniferous tubules at autopsy and there was no peritonitis.

Of the three cases in our series who were discharged to duty without surgical intervention, two received penicillin therapy. While it is in a considerable measure speculative, it is, nevertheless, believed that this drug was a very definite factor in the amelioration of symptoms in these cases. Penicillin was used in the acute phase of three other cases who ultimately came to surgery. There was promptly a notable drop in the temperature of these patients following the administration of this medicament. It is by no means fanciful to consider that Doctor Cutler may have in penicillin another very potent agent to add to his medical armamentarium.

#### SUMMARY

1. A general review of the salient features of regional enteritis has been presented.

2. Surgical features related to the disease have been emphasized. A one-stage surgical procedure was employed in 12 out of 14 operative cases.

3. There was one death which was definitely not due to a surgical complication, but for want of a more plausible explanation was attributed to sulfa drug sensitivity, with a consequent urinary suppression.

4. Penicillin was used in five cases, all of which showed prompt clinical improvement.

5. Three cases appeared to show complete resolution of their disease and were not operated upon.

6. A report of 17 cases of regional enteritis with a tabulation of the common manifestations peculiar to the disease, along with other related data, is added to the literature.

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## THE SECOND FIVE-YEAR PERIOD EXPERIENCE IN TOTAL THYROIDECTOMY

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HAILESTAD, KANSAS

ONE needs to live a lifetime with goiters to appreciate their protean nature. One may compare them, in the abstract, with malignant tumors in that they tend in the end to destroy life. The toxic type, due to epithelial hyperplasia, I long regarded as the most benign because after a stormy period they tended to burn out, leaving the patient with a minimum of ill health. It took me 40 years to appreciate that they, too, ended in a grand finale of cardiac death.

The slowly developing type progressed by degrees so that many years are required before they show their true character. Those who must depend on the written page for these facts are not so well impressed as those who live with these patients so as to be able to see and feel as well as hear this gradual approach to a cardiac death.

Anyone who has taken the trouble to make a study of any goiter cannot fail to appreciate the fact that the part left at operation is of the same structure as the part removed. It is not too farfetched to appreciate the analogy of this procedure with the removal of a part of a malignant lesion. The confusing difference is found in the fact that instead of killing in two years, as is the course in malignant disease, in the case of goiter it is spread over 40 years.

The universal practice of removing a part of the diseased thyroid gland, therefore, was not based on reason but was due to something else, namely to fear. The fear was based on a piece of most unscientific observation by the great Kocher. The dreaded cachexia thyropriva was based on the observation of a single case, a boy aged ten years. Fear is always based on lack of confidence, due to misinformation. The fear that still deters surgeons from performing the obviously needed operation is dependent at the present time on the lack of exact anatomic knowledge.

I confess, with humiliation, that my own approach to the obviously desirable total removal of the goiter, based on the study of the goiter, was stayed by the observation of Kocher and the universal teaching that the thyroid gland was necessary to the individual throughout life. I had to face the fact that should the question be brought to the review of a court I could not depend on the support of a single surgeon. Only Professor A. C. Ivy recognized the fact that the entire thyroid can be removed from adult dogs without bad effects. Kocher scared the daylight out of the whole profession by his observations on a single human puppy.

I was pushed into my first totals by the study of a particular type of gland, uniform in enlargement stationary over many years, uninfluenced by any expectant treatment and made worse by partial removal. I was faced with

the choice of folding my hands in defeat, or doing something. Faced with these facts I reasoned that by removal of the entire gland though the patient would become myxedemic, as the professors taught, I could feed them thyroid extract and make them relatively normal. Much to my amazement these patients did not become myxedemic. Only then, after a rereading of Kocher's original article did I understand that the whole scare was due to bad logic. The major premise ruled. One boy became myxedemic, therefore, all total removals of the gland would be followed by cachexia thyropriva, that was Kocher's reasoning.

This then made it obvious that a study of the whole question of the physiology of the gland was necessary. This made it obvious that this study involved an anatomicphysiologic problem approachable only by the operating surgeon because it involved the study not of a state but of a process. It can be comprehended only by the surgeon working alone. The physiologist leads him astray and the pathologist working separately with only dead tissue merely obfuscates his confusion. The facts have proved this.

This screed has been titled my second five-year period of total thyroidectomies. This is necessary because during the first five-year period it was impossible to gain accurate information. The resident who recorded the operations marked them all "subtotal." Perhaps he felt that if the attorney for the plaintiff asked for the records they would show that some of the gland was left. Patients on leaving the hospital were given thyroid extract without waiting to see if they needed it or not. When the patient returned to the home doctor he vehemently proclaimed that the patient would have to take thyroid extract the rest of his life. When the records showed that the patients were still taking thyroid tablets it was my job to find out if it was needed. This delusion was abetted by the fact that when the ladies began to assume their normal cubic displacement they blamed it on the operation and continued taking thyroid extract, with the approval of the home doctor.

Two factors came about to change the picture. The advent in this clinic of Dr. C. R. Schmidt, long-time assistant of Doctor Ivy, by his work on liver function changed the whole after-course. With the preoperative correction of the lowered liver function the whole picture changed. The patient no longer had the stormy postoperative course and left the hospital recovered. There was no longer any need of postoperative treatment.

More careful operating was a gradual development. It is the experience of all surgeons that as his experience increases complications grow less. These complications had to do chiefly with lessening of nerve injuries and parathyroid disturbances. The parathyroids not only must be left but their blood supply protected. The result of the improvement due to the study of liver function and more careful operating has been such that the chapter in my book covering the first five-year period now appears as a satire and I would have it regarded as such.

My chief aides in establishing total 'ectomy as a method of procedure, as is usual in the experience of surgeons, has been my patients. They leave the



hospital in a week or ten days stepping "high, wide and handsome," declaiming to all and sundry advice and pills.

I had demonstrated to my satisfaction that the thyroid gland having brought us to full development abandons us. This is evidenced by the fact that they do not suffer any physiologic disturbance after its total removal. Based on this evidence I have facetiously remarked that the gland seeing its mistake throws the lever in reverse, so that we will be eliminated at the end of three score and ten. This I will now present as an hypothesis to be checked at the end of the lives of my patients. I have delegated this terminal observation to my grandsons. The study of thyroids of old people supports this hypothesis.

It was necessary to formulate a procedure based on the belief, that the thyroid was concerned with our physical development. Observing young athletes I fixed the age of 21 years as the peak. Therefore, I would perform totals only on individuals above that age. Looking over old records I discovered that I had performed a total on a girl age 16; she was one of our kitchen girls. I sent for her post-haste and was delighted to learn that she was in perfect health, having also lost a disabling dysmenorrhea. Recovering from her operation she went back to her old job of feeding the patients. Since she did not leave the hospital she got no thyroid tablets, nor anything else. This brought to the fore another hypothesis: that the thyroid is concerned only in the development of sex. Since then I have performed totals on all patients who show by their contours that they are sexually mature. I would venture a total on all girls conscious of their shape.

As above noted, with the passing years the complications have gradually grown less. This leads me to a discussion of the technic—no radical changes have been made but greater care in detail has been the constant endeavor.

The first essential is operating under local anesthesia. Only by so doing does one obtain a bloodless field, making details of structure visible. Retractors and protecting frames are not used.

Only from a cross-sectional anatomy does one obtain a picture of the relation of gland capsule, of the recurrent nerves and the parathyroids. These structures are said to sometimes lie inside the capsule. Perhaps in some regions but not in Kansas. I do not believe this is possible considering the embryologic development. In order to obtain a picture of the relation and extent of the fibrous capsule it is necessary to study the slides stained with a specific fibrous tissue stain. Tom Jones has made a careful drawing of such sections (*Diseases of the Thyroid Gland*, Hoeber, 1941).

The essential thing is that nothing, absolutely nothing, is grasped with forceps until it is identified. The arteries are easily enough recognized. The lateral veins are so thin that when there is traction on the gland they are empty and appear only as thin bands of fascia. This is particularly true of septas between the lobules of complicated glands. All these septas contain veins which must be grasped before they are cut.

In ligating the vessels after the lobe has been removed we stick through

a bit, a very small bit of tissue, just enough to prevent the ligature from slipping. If this is not done, coughing may throw the ligature from the end of the vessel. I have seen this happen before the wound was closed.

The recurrent nerve is most apt to be endangered at the lower pole. Lahey has well shown that elevation of the lower pole brings the nerve with it. We do not expose the nerve but we stay above it and are sure we are not grasping it because we see before we use the forceps. In the light of my present knowledge I cannot understand how any nerve ever escaped my mass ligations in my early operations—too many did not.

But that is not the whole story. Sometimes after some hours or days the vocal cords become involved. In a few days this clears up. The cords appear normal and the best explanation is that the nerves become edematous which interferes temporarily with their function. Sometimes the larynx becomes edematous and the mucus becomes annoying. Steam inhalations lessen this difficulty.

This obstruction may be so great as to require a tracheotomy. After a few days the tube can be removed, and curiously enough the wound heals without infection. The need for tracheotomy has lessened to the vanishing point. Why, I do not know, except that a more careful technic to grasp nothing but vessels has gradually developed.

Collapse of the trachea sometimes requires a tube. This is most likely to follow in old colloid goiters with calcification. If the trachea is soft we remove only one lobe. When that wound is healed the other lobe is removed. Attention to this point has eliminated this difficulty, except sometimes the softness of the trachea is not appreciated until the second lobe is removed. In such cases a tube is placed before the wound is closed. Such events have become rare indeed. The chief objection to placing a tube is that it gives one a sense of humiliation, just should not be. It hurts the surgeon more than the patient.

Tetany has become a very rare complication since we are careful to separate the parathyroids from the capsule above the gland, being careful to respect the supplying vessel coming up from below. In some cases there is tingling for a few days with a lowered calcium content. We should have calcium determinations before operation.

A word of caution is necessary as to what to expect from a total 'ectomy. It will relieve only those symptoms due to the goiter. This means that a careful general examination is necessary before operation. A total 'ectomy will not solve the problem of the fear of pregnancy, the blonde secretary, nor the income tax man, to mention only the most common; and now the worry over the safety of Johnnie overseas.

I may say that B. M. R.'s are done before operation by a very competent technician of years' experience. Also, no one pays any attention to the findings. Anyone who admits that a tin can knows more about goiters than he does has not become acquainted with the rudiments of the goiter problem.

We suffer now chiefly from the sins of others. It is a dull day which

does not present at least one patient who has been previously operated upon elsewhere. We divide these into two groups: Those who have been operated "at" and those who have been operated "upon." The first are the work of amateurs who leave all or nearly all of the gland, producing only a superficial excoriation. This offers few difficulties at the second operation. Those operated upon by capable surgeons may offer real problems. If the patient has not been relieved of the symptoms due to goiter, we know they have some goiter left, whether one can feel anything or not; to this there are no exceptions. There may be only the heart sounds to go on after a delayed convalescence. If the operator has removed most of the gland, perhaps dislocated it to see how much he has left, perhaps cut the ribbon muscles, one may have a real problem. Only a strip covering the recurrent nerve may remain. Here one finds his best lead at either pole. One may need to expose the nerve to be sure where it is located. Where the parathyroids are located only a "New Dealer" can tell.

These labors have their rewards. These patients know when they have been relieved of the offending gland which has caused their trouble. This is true chiefly in the acute toxic of course with cellular hyperplasia. The colloid goiters are different. The degeneration comes slowly and finds expression in the goiter heart. They are improved by biopsies and may be quite happy for years. I have had plenty of experience with my own patients some 20 or 30 years after. Operated upon in those early years they still haunt my doorstep.

As a corollary, I may refer to the spontaneous myxedemics. A total 'ectomy relieves the myxedema in some cases, and they bear healthy children. That is a problem for the physiologist. Myxedema is a complicated problem about which no one knows much. There are two classes, one with goiter, which show Hashimoto cells require total 'ectomy and those in which all vestige of thyroid tissue has disappeared. Exploration of the neck yields nothing.

What are the indications for total removal? The presence of a goiter in which there is evidence of hyperplasia. This is signalized by hyperactivity or bosselations. Enlargement due to physiologic disturbance may recover. Those complicated by "chronic appendicitis," that is to say ovarian pain, nearly all recover, even in spite of an appendectomy. A few of these pass into a state of hyperplasia requiring operation.

#### COMMENT

The controversy of the advisability of total thyroidectomy is a thing of the past. The vastly improved results quiets all discussion. We have specimens, slides and hospital records of upwards of 4,000 patients upon whom we performed total 'ectomies. The complications are gradually lessening, which indicates that even greater care in technic is needed. We are delighted with our results, but not satisfied. So long as a single untoward result follows, the technic must be perfected. The basic surgical problem has been

solved. The relation of the thyroid gland to the life span is a problem for the physiologist. It cannot be solved by edict. The fact that it has been demonstrated that physically mature persons when relieved of all their visible thyroid tissue enjoy good health, calls for a reëxamination of some basic problems on the part of the physiologist.

We have had no experience with thiouracil. Even those with the most experience are uncertain of their results. That a cure ever results seems to ignore the pathology. We have found that with a careful attention to the liver function on patients not losing weight a total thyroidectomy is followed by little postoperative reaction. There is also the satisfaction of knowing what the slide shows.

# AINHUM (DACTYLOLYSIS SPONTANEA)

REPORT OF TWO CASES FROM ILLINOIS

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THE TERM AINHUM (*ān'hum*) is of African derivation, meaning to saw or to cut, and is given to a curious disease peculiar to the dark-skinned races, especially the Negro. It is characterized by a linear, narrow, fibrous constricting band beginning at the digitopltantar fold of the little toe. This constriction becomes deeper and deeper and produces a strangulation of all the tissues under the ring together with an absorption, and many times a pathologic fracture of the bone. Gradually the distal end of the toe becomes enlarged, bulbous and remains attached by a mere pedicle. Eventually there is spontaneous amputation of the toe, sometimes hastened by injury or gangrene.

According to Spinzig,<sup>1</sup> Clark, in 1860, described a condition of dry gangrene of the little toe among the natives of the African Gold Coast and this is thought to be the first recognition of the disease later known as ainhum. A Brazilian physician, da Silva Lima (cited by Spinzig), first described and introduced the name ainhum in 1867, and the first pathologic studies were made by Wucherer, in Bahia, Brazil.

Most of the cases of ainhum have been reported from South America, Africa, the West Indies, India, Central America, and Madagascar. It is a rare disease in the United States and extremely rare in the northern part. All patients reported in the United States were born south of the Mason-Dixon line except two, one in Ohio and another in Illinois. A search of the American literature reveals only one case previously reported from Illinois, and that by Dr. James B. Herrick<sup>2</sup> in the Chicago Medical Recorder in 1897.

Spinzig,<sup>1</sup> in 1939, analyzed 41 cases which included three reported by him. Since then ten cases, including our two, have been reported (Table I). The total is 51 cases in the United States since 1881, and the second and third cases from Illinois.

## CASE REPORTS

**Case 1.**—L. S., a colored male, age 39, was born in New Orleans, Louisiana, where he lived until he was 11 years old. He then moved to Chicago, Illinois, where he has resided for the past 28 years. Two years ago he noted for the first time a constricting band about the base of the fifth toe of his left foot. The constriction was associated with pain in the toe. A soft corn was noted in this location previous to the onset of this constricting band.

In July, 1943, he was admitted to the Cook County Hospital for a head injury. At that time a diagnosis of ainhum was made and amputation of the toe advised, which he refused to have done.

By taking hot foot baths twice daily for relief of pain, the patient managed to work the 18 months prior to entering the hospital. With the onset of cold weather in December, 1944, he began to have severe pain in the toe which interfered with walking and working. He entered Cook County Hospital, January 5, 1945, for amputation.

His personal and family histories were negative. The physical examination was completely negative except for the left fifth toe which was characterized by a deep band-like constriction following the digitopltar fold which gave the distal portion of the toe a bulbous, edematous, pedunculated, strawberry-like appearance, with dermatitis and superficial ulceration between the toes. The toe was tender and painful upon manipulation. With warm soapy foot soaks the inflammation subsided.

The roentgenographic examination revealed soft-tissue constriction, with pathologic

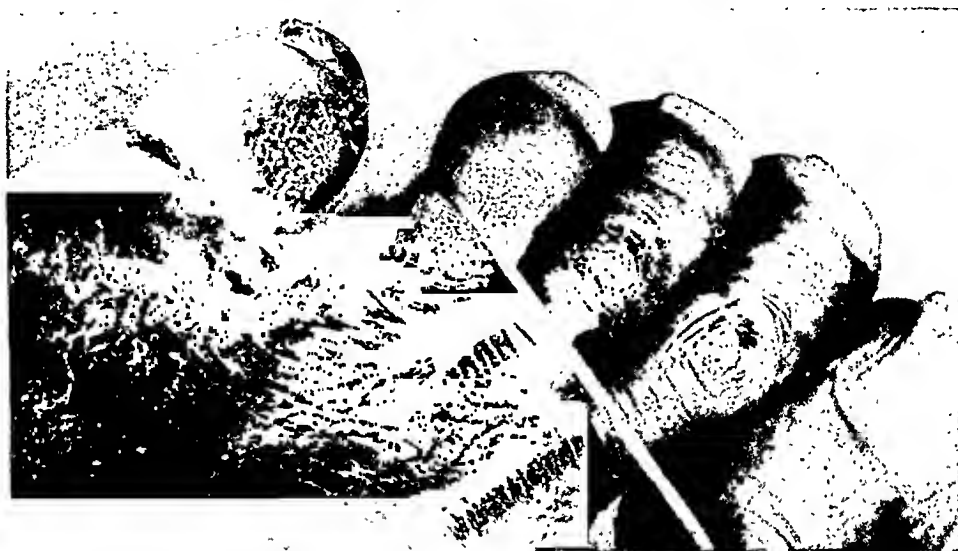


FIG. 1.—Case 1. (L. S.): Photograph of toes of left foot showing soft-tissue constriction of fifth toe due to ainhum. Note characteristic outward rotation of this toe.

fracture and atrophy of the proximal phalanx of the left fifth toe, with rotation of the terminal phalanx.

The urine and blood were normal, and the Kahn test was negative.

Under sodium pentothal anesthesia, a metatarsophalangeal disarticulation of the left fifth toe, with removal of the distal end of the fifth metatarsal, was performed.

Recovery was uneventful except for an upper respiratory infection which promptly responded to treatment. Healing was by first intention, and the patient was discharged from the hospital 11 days postoperative.

**Case 2.**—C. G., a colored male, age 47, was admitted to the Edward Lewis Surgical Service at the Cook County Hospital on February 17, 1945. He was born in Louisiana, had lived in many of the southern states, and had been a resident of Chicago for the past 17 years.

He first noticed an indentation on the dorsum of the right little toe two and one-half years ago. Aside from a painful corn over this toe, he had no difficulty until six months ago when the pain became constant, gradually increasing in severity, and was present whether the patient wore shoes or not. Immediately prior to entering the hospital he was unable to sleep because of the pain.

Nine years ago he noticed a constricting band about the base of the left fifth toe. It produced no symptoms until it was struck accidentally by a lump of coal. One week later the toe sloughed off. The defect healed uneventfully.

TABLE I  
ANALYSIS OF CASES OF "AINHUM" REPORTED IN THE U. S. SINCE REPORT BY SPINZIG IN AUGUST, 1939

Author	Year of Report	Place Where Case was Seen	Birth Place	Age	Sex	Race	Heredity	Duration of Symptoms	Age at Onset of Disease	Toe Involved	Early Pain?	Late Pain?	History of Injury	Ulceration	Amputation	Lesion at Onset?	Remarks
42 Bennett <sup>4</sup>	1938	Ala.	C.M. Ga.	42	M	Negro	No	5 yrs.	37 yrs.	R. and L. 5th	Yes	Yes	No	No	Yes	Surgery	Bilat. sympathect. Lumbar transperitoneal
43 McKnight <sup>5</sup>	1940	N.C.		45 ?	M	Negro	No	1 yr.	44 yrs.	5th L. 3rd, 5th R.	Yes	Yes	No	No	Spontaneous—all	No	
44 Gerwig and Warner <sup>6</sup>	1941	Md.	W.A. Md.	42 yrs.	42	M	Negro	No	2 mos.	42 yrs.	Yes	Yes	No	No	Yes	Surgery	Recur. in L. 5th and R. 4th, 17 yrs. after onset in R. 5th
45 Gerwig and Warner <sup>6</sup>	1941	Md.	R.J. S.C.	20 yrs.	41	M	Negro	9 mos.	41 yrs.	R. and L. 5th	No	No	No	No	Yes, left. Spon. on right	No	Luetic
46 Teske <sup>7</sup>	1941	Ala.	W.A. Ala.	49 yrs.	49	M	Negro	No	1 yr.	48 yrs.	No	Yes—R. 5th	No	Yes	Yes	Yes—itching	Luetic keratosis. Palmaris and plantaris
47 Spencer <sup>8</sup>	1942	N.Y.	G.F. Texas	17 yrs.	44	M	Negro	No	10 yrs.	34 yrs.	Occ.	Occ.	No	Yes	Surgery	Yes—corns	Old fracture rt. ankle
48 Usery <sup>9</sup>	1944	Ala.	J.G. Ala.	71 yrs.	71	M	Negro	1 mo.	71 yrs.	R. 5th	Yes	Yes	No	Yes	Yes	Yes	
49 Goehring <sup>10</sup>	1944	Penn.	P.B. Ala.	17 yrs.	43	F	Negro	No	1 yr.	42 yrs.	Yes	Yes	No	No	Surgery Bilat.	No	
50 Vaughn, Howser, Shropshear	1945	Ill.	L.S. La.	28 yrs.	39	M	Negro	No	2 yrs.	37 yrs.	Yes	Yes	No.	Yes	Yes	Yes—soft corn	
51 Vaughn, Howser, Shropshear	1945	Ill.	C.G. La.	17 yrs.	47	M	Negro	No	2.5 yrs.	44 yrs.	No	Yes	No	No	Yes	Yes—L. spon. R. surg.	soft corns both toes

There is no family history of ainhum.

On admission to the hospital the essential findings were limited to the fifth toe of the right foot which presented a soft-tissue constriction at the digitopltantar fold and appeared ankylosed.

The roentgenographic examination revealed a pathologic fracture through the shaft of the proximal phalanx of the right fifth toe in the region of the constricting band, while the left fifth toe had been spontaneously amputated previously through the proximal phalanx.

The urine and blood were normal, and the Kahn test was negative.

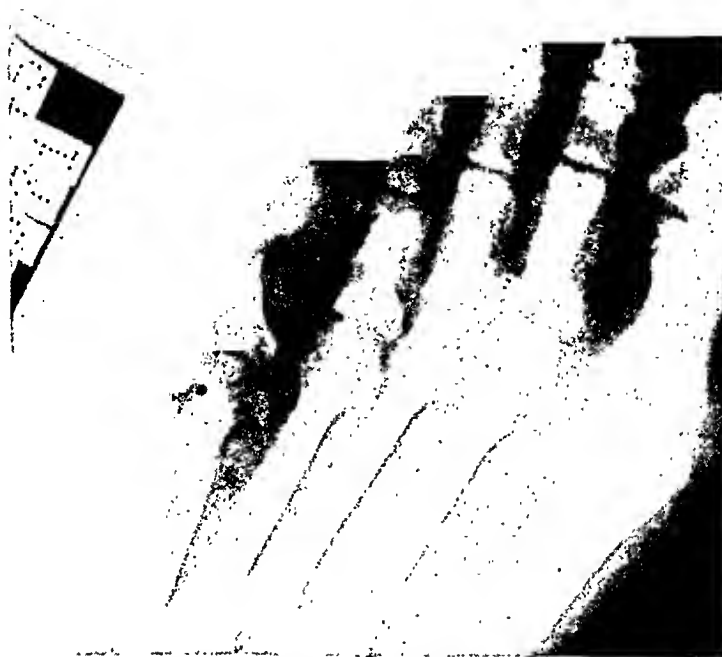


FIG. 2.—Case 1. (L. S.): Anteroposterior roentgenogram of left toes. Note osseous changes in the fifth toe. The proximal phalanx is narrow, the cortex thinned, and there is a pathologic fracture, with rotation of the distal phalanx.

Under sodium pentothal anesthesia, a metatarsophalangeal disarticulation of the right fifth toe was performed on March 5, 1945. Healing was by first intention and the patient was discharged from the hospital a few days later following an uneventful convalescence.

#### ETIOLOGY

The etiology of ainhum is not fully understood. Numerous theories have been advanced from time to time but none offer a satisfactory explanation for all cases. The *leprosy* theory, advanced by Zambaco Pacha, and others, has been abandoned since leprosy affects white and colored alike, whereas ainhum affects the colored races almost exclusively. Bacteriologic and histologic studies have found no evidence of leprosy.

*Syphilis* has been present only in a minority of the cases.

*Infections and parasites* as the Chigre would not affect the dark-skinned races exclusively.



To call it an *annular scleroderma* merely begs the question of etiology and ignores the racial factor.

The term *trophoneurosis* does the same.

*Mechanical injury* by the wearing of a ring or irritation by sand or gravel in barefooted people seems not directly causative since the condition occurs in ringless and well-shod patients.

The susceptibility of the colored race to fibrous tissue overgrowths (keloid) aggravated by injury to exposed parts has been cited as a possible cause by Pusey.<sup>3</sup>

Heredity suggested as a factor by earlier writers played no part in the ten cases analyzed by us.

Males are predominantly affected. Spinzig, in 41 cases, found the ratio of male to female two to one. In the ten cases reported in the United States since 1939, nine are males and one female (Table I).

The disease occurs almost exclusively in the dark-skinned races, especially the Negro. Cases occasionally have been observed in Arabs, Hindus, Musselmans, Mongolians, and Chinese. According to Spinzig, only one white patient has been reported in the United States, and that case, in his opinion, was a complication of uncinariasis, an "ainhum-like" process, and was not included among his 41 "true" cases.

The lesion involves one or both of the little toes usually. In the ten cases analyzed by us (Table I) the left fifth toe was involved only once, the right fifth in three cases, bilateral fifth in five cases, the left fourth and fifth and the right third and fifth in one case. Pusey<sup>3</sup> agrees that the fifth toe is usually involved, but states that the fingers as well as toes are affected in a few cases. Spinzig believes that this latter type of involvement is probably due to the "ainhum-like" scar constrictions, and not true ainhum. No cases reported in the United States have occurred in the fingers.

#### SYMPTOMS

The symptoms of ainhum are purely local. There are no constitutional symptoms. The disease is characterized by the formation of a fissure or partial circular constriction in the skin beginning usually at the fifth digitoplantar fold on the inferior medial aspect. A warty soft corn is described as sometimes being present at the onset of the disease. This was found to be present in three of the ten cases reviewed by us. Spinzig had eight cases with corns, calluses or warty growths at the onset of the disease. The fissure or furrow may appear on one fifth toe, the other remaining normal or becoming involved later, or it may appear simultaneously in both toes. Symmetry is the rule. The fissure deepens, spreads laterally and dorsally until the two wings connect on the dorsum of the foot. The toe eventually becomes completely encircled and the furrow becomes deeper and narrower as if a tight rubber band or ligature had been placed around it. This process continues until the toe remains attached by a mere slender pedicle. The bone, too, is constricted and may fracture. Beyond the ring of constriction the toe becomes enlarged,

bulbous and globular presenting the appearance of a strawberry or cherry attached to the foot by a pedicle. The nail usually remains and the skin becomes thick, dry and tough.

Early pain was recorded in six of the ten cases reviewed by us, although many writers have not found this symptom early. Late pain is usually present, especially after a pathologic fracture. In the series reviewed by us late pain was present in nine cases and in one case there was no pain. Spinzig's series recorded late pain in 34 cases, no pain in two cases, and no information was



FIG. 3

FIG. 3.—Case 2. (C. G.): Photograph of toes of right foot showing soft tissue constriction of fifth toe due to ainhum. Note hyperkeratotic changes of toes, with characteristic outward rotation of fifth distal phalanx.

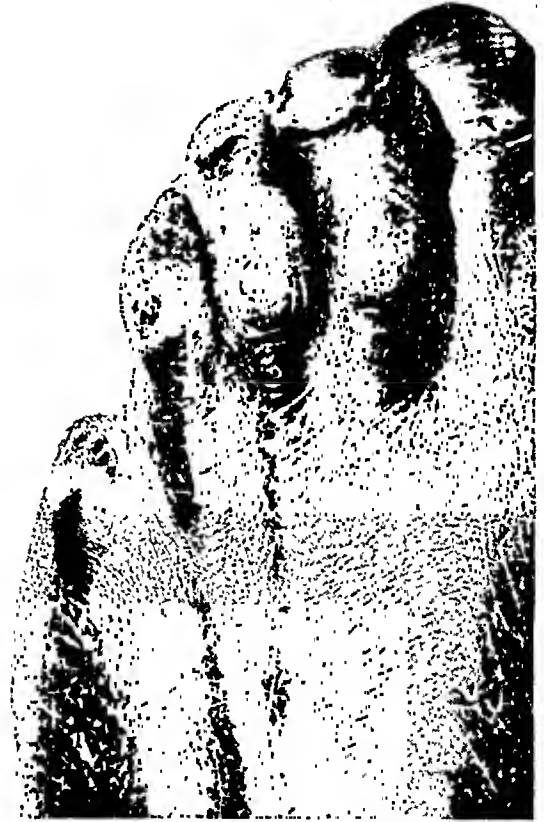


FIG. 4

FIG. 4.—Case 2. (C. G.): Photograph of toes of left foot showing absence of left fifth toe which was amputated spontaneously. Hyperkeratotic changes also present.

available in the other cases. Spontaneous amputation occurred in one or both toes in three cases in the series reviewed by us. There usually in no ulceration nor inflammatory signs at the onset of the disease. Ulcerations may occur late in the disease. Spinzig found seven cases of late ulceration in his series and we four cases.

The symptoms may extend over a period of years. The duration of the disease in the cases reviewed by us was from one month to ten years.

#### PATHOLOGY

At the site of the constriction there is a proliferation and hyperkeratosis of the surface epithelium, and fibrosis of the corium beginning at the digitopltantar

FIG. 5



FIG. 6

FIG. 5.—Case 2 (C. G.): Photograph of toes of both feet, plantar surface, with ainhum involving the right fifth toe and an absence of the left fifth toe. Hyperkeratotic changes are present on both feet.

FIG. 6.—Case 2. (C. G.): Anteroposterior roentgenograms of both feet. Ainhum constriction on right fifth toe. There is marked thinning of the distal end of proximal phalanx and complete destruction of bone under the constriction, with rotation of the distal phalanx.

Left foot shows stump of proximal fifth phalanx following spontaneous amputation.

fold. Endarteritis and periarteritis develop distal to the band. There is some perivascular infiltration of round cells. There is gradual connective tissue replacement of all the elements of the skin and subcutaneous tissues. The



FIG. 7.—Case 1. (L. S.): Longitudinal section of toe. ( $\times 5$ ). Note hyperkeratosis of surface epithelium and fibrosis of corium.

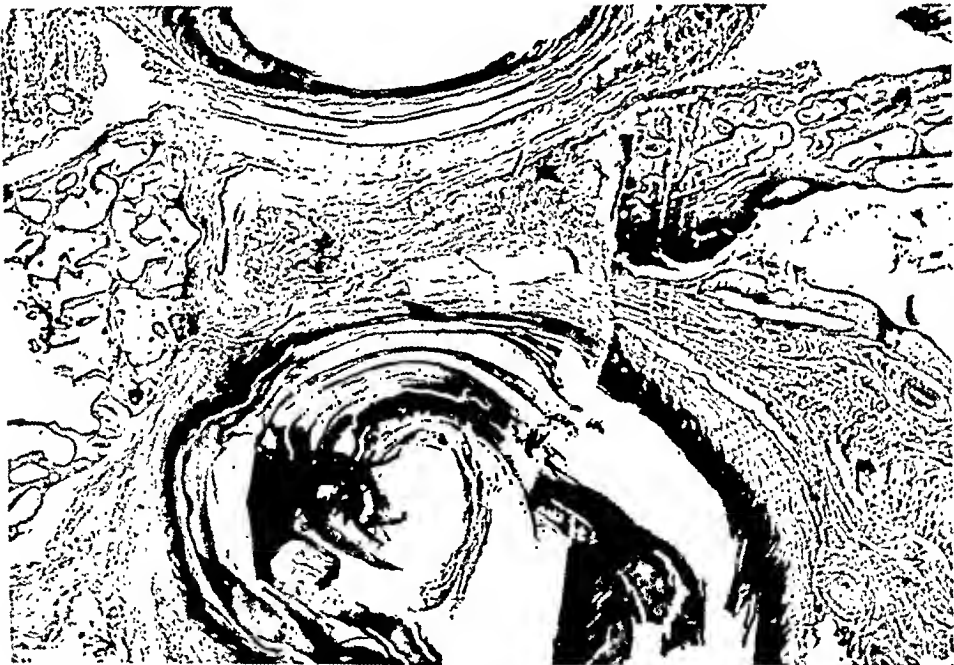


FIG. 8.—Case 1. (L. S.): Longitudinal section of toe. ( $\times 12$ ). Note fibrous tissue replacing bone at site of pathologic fracture.

constricted bone shows a rarefying osteitis. The constriction usually involves the shaft of the proximal phalanx of the fifth toe. The two distal bony phalanges remain surprisingly intact but occasionally show rarefaction and even fragmentation.

## ROENTGENOGRAPHIC FINDINGS

The characteristic roentgenographic findings are narrowing of the shaft, thinning of the cortex of the phalanx, pathologic fracture and rotation of the distal phalanx.

In Case 1, the proximal phalanx of the left fifth toe is constricted, the cortex is thin and there is a fracture at this point, with rotation of the distal phalanges. Case 2 reveals complete absorption of the distal half of the right proximal phalanx, with rotation of the toe. The left fifth was already spontaneously amputated. The proximal one-third of the proximal phalanx remained.

## DIAGNOSIS

The condition is so unique and characteristic that diagnosis is easy except when seen for the first time. One who is unfamiliar with ainhum may mistake it for leprosy, syringomyelia, Raynaud's disease, neurotrophic ulcer, fissure due to injury, sclerodactylia, scleroderma, or congenital constriction from an amniotic band even after radiography, as happened in our second case.

## PROGNOSIS

The general health is in no way affected. If the surgeon does not amputate the toe, nature will, but more slowly. The use of the foot is not impaired by the amputation.

## TREATMENT

A metatarsophalangeal disarticulation, with removal of the metatarsal head, is the operation of choice.

## SUMMARY

1. Two additional cases of ainhum are reported from Illinois. The first case reported from Illinois was in 1897, by Dr. James B. Herrick.

2. A search of the American literature reveals these to be the fiftieth and fifty-first cases, respectively, reported in the United States and the second and third from Illinois.

3. Ten recorded cases, including these two, occurring in the United States from 1939 to 1945 are analyzed.

4. With the present influx of colored labor entering the United States from the West Indies, a preemployment examination of the unshod foot by the industrial surgeon is indicated, since this disease may be more prevalent than formerly considered and may pass unrecognized.

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# OBSERVATIONS ON THE SURGICAL TREATMENT OF HERNIA

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IN PREVIOUS PUBLICATIONS<sup>1, 5</sup> I called attention to certain facts in regard to the etiology and treatment of inguinal hernia. From this research and experimental work sufficient knowledge was gained to convince me that there existed in human beings a true inguinal sphincter about the internal abdominal ring and that the problem of the cure of inguinal hernia was intimately connected with the proper functioning of this sphincter.

A particular interest in hernia led me to conduct various experiments. Relying on dissection alone, either on cadavers or dogs, was discouraging, as there were times when I could demonstrate this sphincter but others when I was not so certain. Then I realized that the presence of a sphincter is proved by observing its action; experimental work on dogs *in vivo* was conducted, and stimulation of the sphincter itself or of its nerve supply (a branch of the ilio-inguinal nerve) by means of the induction coil definitely proved that a sphincter did exist. This work is fully explained in the articles mentioned. However, since the operation necessary to demonstrate this action can hardly be performed on a live human being, the difficulty of presenting conclusive anatomic proof that this sphincter exists in human beings is clear. The best evidence that it does is that cases of inguinal hernia behave as though it did, and experimentation on live dogs shows that they possess this sphincter.

Zimmerman<sup>3</sup> states: "The importance of the internal oblique muscle in safeguarding the inner opening of the inguinal canal cannot be over-emphasized. Its action has been likened to that of a sphincter or shutter. . . . The efficacy of this sphincter can be demonstrated when local anesthesia is used in operations for indirect hernia. If a finger is inserted into the sac, extending into the abdominal cavity, and the patient strains or coughs, the muscle can be felt contracting down upon the finger like a true sphincter." Zimmerman's observations are in keeping with my own. I should like to add, however, in connection with the "shutter-like" action which various writers describe, that as I experimented with dogs, I found that always the internal ring either contracted *in toto* or not at all, thus, behaving like a true sphincter instead of a shutter.

Although the findings of Schragar and Gault<sup>2</sup> were not in accord with mine, their results were based upon dissections alone and do not vitiate my conclusions, I realize that at operation it is difficult and sometimes impossible to demonstrate this sphincter, however, this is not surprising when one considers the distortion due to the dilating effect of the hernial sac and contents, nevertheless, the plastic stitch upon this sphincter as advocated,<sup>5</sup> has given me better results over a long period of use than other methods.

Again, Harkins and Swenson<sup>4</sup> advocate a stitch in the transversalis fascia

about the cord, without its suture to the inguinal ligament, in order to restore the tonicity of the ring. This is practically the same procedure as I<sup>5</sup> suggested, and the theory upon which their technic is based appears to be thoroughly in harmony with mine.

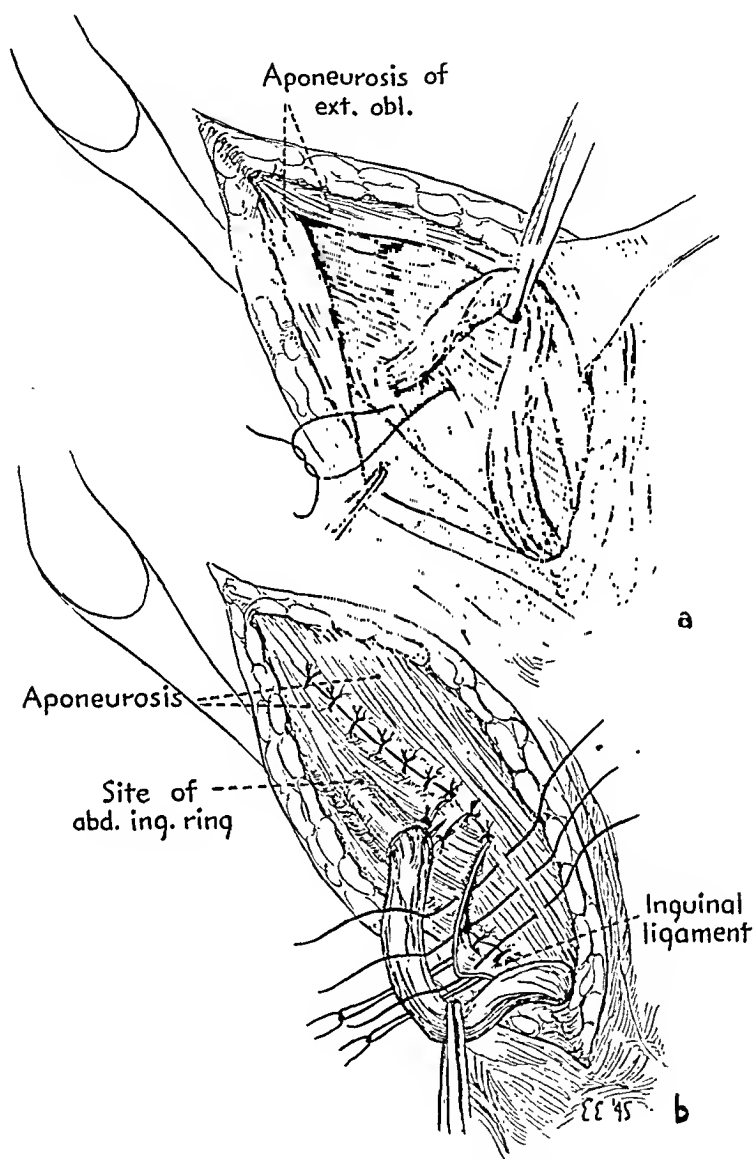


FIG. 1.--(a) MacGregor stitch in the muscle structures about the cord, producing a snugness of the internal inguinal sphincter. This unites the fibers of the internal oblique and transversus muscles and does not include the inguinal ligament; or injury to the nerves. Two stitches may be used when the ring is greatly dilated. This and Figure 1b completes the operation.

(b) Showing the combination Stetten-Scott closure. All sutures are tied external to the aponeurosis of the external oblique and a small V made in the upper flap opposite the cord. Note the exit of the cord in relation to the internal abdominal ring.

My treatment of hernia based upon the existence of this sphincter, which I<sup>5</sup> described in "The Fundamental Operative Treatment of Inguinal Hernia," in 1930, has proved most successful up to this time in 357 cases, and recurrence has been very infrequent. Since I described my technic in that paper,



however, I have had occasion to modify it in certain respects. I wish here to describe these modifications.

In the first place, where indirect hernia is large and of long standing, I now put two stitches instead of one in the lower part of the muscular ring which surrounds the cord at the internal abdominal ring, following the same principles, of course, as in the original procedure (Fig. 1-a). Since, as I believe from my research work, it is the giving away of the internal inguinal sphincter which is the principal cause of the hernia, this simple procedure is practically all that is necessary.

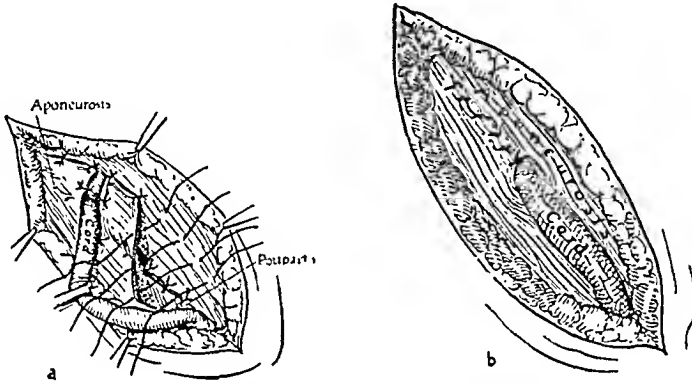


FIG. 2.—(a) Shows Stetten's method of closure, and the overlapping of the aponeurosis.

(b) Scott's method: Brings the cord through the overlapped aponeurotic flap at a point half way down the line of incision. This gives an oblique inguinal canal and permits the lower end of the wound to be closed firmly. (Watson—Hernia. 2nd Ed. 1938, Mosby.)

Secondly, I said in my original article<sup>5</sup> that the subsequent closure of the canal and the incision may be left to the choice of the operator, though I recommend the Willys-Andrews closure. Now, however, I pay little attention to the internal oblique or transversus muscles except in some instances which I shall explain later. I now use the Stetten<sup>6</sup> principle of closure (Fig. 2-a), but modify this slightly so that the opening in the aponeurosis of the external oblique is slightly below the exit of the cord (Fig. 1-b). This method preserves the oblique position of the cord in relation to the internal abdominal ring, and in this respect is based on Scott's technic (Fig. 2-b). The combination of the two is illustrated in Figure 1-b, it is to be noticed that all suture knots are tied outside the canal and that a small relaxing cut is made in the aponeurosis opposite the exit of the cord. A new roof is made by suturing Scarpa's fascia carefully over this. I prefer this method to a technic whereby the cord is placed on the internal oblique, and the aponeurosis of the external is sutured over and a new external abdominal ring is made. This is the Bassini closure, and my criticism of it is that an aperture is left in the suture line of the external oblique aponeurosis opposite Hesselbach's triangle. This aperture weakens the posterior wall and predisposes to a direct hernia.

I always clean the aponeurosis of the external oblique muscle of the thin

membrane that covers its surface, since it heals better when freed of its overlying aerolar tissue. Studies<sup>8</sup> of the blood supply of the aponeurosis of this muscle show it contains very few blood vessels, but that the membrane to which I refer contains a fine network of nutrient vessels. These facts would appear to constitute an argument against removing it before beginning plastic repair. However, fascia or aponeurosis maintains its nutrition through its lymph supply.

I should like to emphasize the fact that it is essential that throughout all the manipulations no injury be done to the ilio-inguinal or the iliohypogastric nerves, since traumatization of their motor fibers may defeat the purpose of the entire operation by producing a degenerative paresis of the internal inguinal sphincter. The hernial sac, of course, is always opened, explored, and after ligation, is not anchored to the abdominal wall as a cone-shaped process is to be avoided, and, further, it is important to remember that structures should never be sutured under tension.

I find that I disagree with certain aspects of operative technic recommended by recent writers. For instance, McVay<sup>9</sup> states "that there is no justification for suturing the transversalis fascia or any other inguinal strata to the inguinal ligament—that the transversalis fascia, the aponeurosis of the transversus abdominis muscle, and the internal oblique muscle (when present in this location) should be sutured not to the inguinal ligament but to Cooper's ligament; the inguinal ligament is a frail structure easily elevated from its fascial bed and in no way a suitable substitute for the normal anatomic insertion, which is Cooper's ligament." Incidentally, the suturing of the transversalis fascia and the inguinal oblique aponeurosis to Cooper's ligament was well described and well illustrated by Wayne Babcock,<sup>10</sup> in 1927, who found it quite effectual in direct hernia as well as preventing femoral hernia. He cautions, however, that "care must be taken that the suture line is not carried so far laterally as to impinge on the femoral vessels." For this reason and the fact that too much tension may be on the suture line, I prefer the technic as outlined.

Most text books,<sup>11</sup> however, say that the aponeurosis of the internal oblique and transversus abdominis are inserted together into the crest of the os pubis and pecten pubis, forming the inguinal falx. Now, if one examines closely the inguinal ligament he will see that it is reflected from the pubes as the lacunar ligament and that a little more laterally, as it runs along the ascending ramus, it becomes Cooper's ligament. How far these muscles extend down before becoming tendinous is, I think, a matter of development; likewise, I can see that the same may be said about their insertion; naturally, where this insertion is more lateral and posterior into Cooper's ligament, as mentioned, Hesselbach's triangle is greatly strengthened and direct hernia is not so likely to occur.

Furthermore, I cannot quite agree with the statement that the inguinal ligament "is a frail structure." My experience in the dissecting room and at the operating table is that if you get the deep shelving portion or true

ligament, it is a white glistening structure and not easily elevated. This appears reasonable when one considers that it is held down and continuous with the fascia lata of the thigh and medially with the iliopsoas fascia and more medially with the lacunar ligament and Cooper's ligament. Under certain clinical conditions it can be used to anchor fascial structures. I notice further, that in excellent papers, published in 1938 and 1940, Zimmerman<sup>3, 13</sup> sutures the transversalis fascia to the inguinal ligament and follows the concept of fascia-to-fascia without tension.

In direct herniae, I invariably follow the technic of Hoguet,<sup>14</sup> whereby the peritoneum at the internal ring is demonstrated by making slight traction on the cord. The peritoneum is then opened and the finger inserted, a procedure which insures that the bladder will not be injured, and the direct hernia is converted into an indirect. This is repaired by restoring the snugness of the internal ring, as described in my original article.<sup>5</sup> The transversalis fascia can be overlapped on itself, or taken up by a purse-string suture, or sutured to the inguinal ligament and the triangle further strengthened by a modification of Downes' technic, as suggested by Fallis,<sup>15</sup> whereby an incision two or three inches long is made a little to the midline of the lateral border of the rectus sheath, with the handle of the scalpel freeing the sheath from the muscle underneath for quite some distance, especially medially. This procedure relieves the sheath from the pull of the opposite side through the linea alba and allows it to be brought over to the inguinal ligament, and combined with the modified Stetten's closure, completes the operation. In both indirect and direct hernia I transplant the cord as mentioned. Criticism, if any, of this procedure is that the cord structures may be strangulated. And my answer to this is, frankly, not if it is done correctly.

Since reporting this work,<sup>1, 5</sup> I realize that my series of 357 cases is not very large; 273 were of the indirect type and include pantaloon type as well as those complicated by hydrocele of the cord or of the scrotum or of a sac within a sac. Contacts have been made with III and two recurrences noted (1.8 per cent). Eighty-four of the 357 were of the direct type, and 34 traced with one recurrence (3 per cent). The recurrences in the indirect type occurred before I began using two stitches in the internal sphincter in cases where the ring was greatly dilated. Most of these cases were switchmen and sectionmen whose occupation subjects them to quick falls or slips especially while lifting, and it is interesting to note how this etiology fits in with that previously reported.<sup>1</sup> The recurrence in the direct case was on a very large, rather stout section hand, I used the technic as described, but it recurred, and was reoperated. In fairness I may say that he went back to heavy work sooner than advised.

In conclusion, I wish to say a word about the Bassini type of operation. Some years ago, as an intern in Harper Hospital, I noticed that this was the operation most frequently performed. We now know that recurrences were very high, 20 per cent or over. On the other hand, we know that some of

these Bassini cases did obtain a good result. Why was this? Muscle bundles deprived of function by surgical interference or disease atrophy and leave only connective tissue, and when they are forcibly pulled out of their natural line and sutured, what union does take place is in a thin nonresisting layer of scar tissue. Therefore, in children with immature muscles and in adults with strong muscles, the Bassini is sometimes harmful. But in older persons and cases where the muscles are frequently stretched, as we sometimes see in direct hernia, the internal oblique and transversus (conjoined tendon) may be brought over with the upper flap of the aponeurosis of the external oblique under the cord and sutured to the inguinal ligament, in this instance acting merely as a buffer to help strengthen the aponeurosis. So it was probably in some of these cases with high ligation of the sac that the Bassini was of value and constituted a cure.

#### SUMMARY

Attention is again called to the suture of the internal inguinal sphincter, as first advocated by me in 1930, as a result of my original research work in 1929. The use of this technic over 14 years has convinced me that high ligation of the sac without anchorage to the abdominal wall, and transplantation of the cord with a modified Stetten's closure is all that is necessary in indirect herniae. The suggestions given for the repair of direct hernia and indirect hernia are based upon etiologic, physiologic, and anatomic studies.

Note: There are many points on symptoms, subjective and objective, which I should like to dwell upon for the benefit of the intern and students; but space will not permit. Let me say, however, that in making difficult differential diagnoses between a direct and indirect hernia, a helping point is that a direct hernia does not have a tunica vaginalis and, consequently, never enters the scrotum, while an indirect one does have, and may or may not enter the scrotum.

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vessels and fastening the skin towels to the skin edges, the edges of the wound are retracted, exposing the aponeurosis of the external oblique.

3. The fibers of the external oblique are slit in the direction of the skin incision, and by blunt dissection the upper edge of the cut aponeurosis is separated inward and upward, exposing the falx inguinalis and part of the

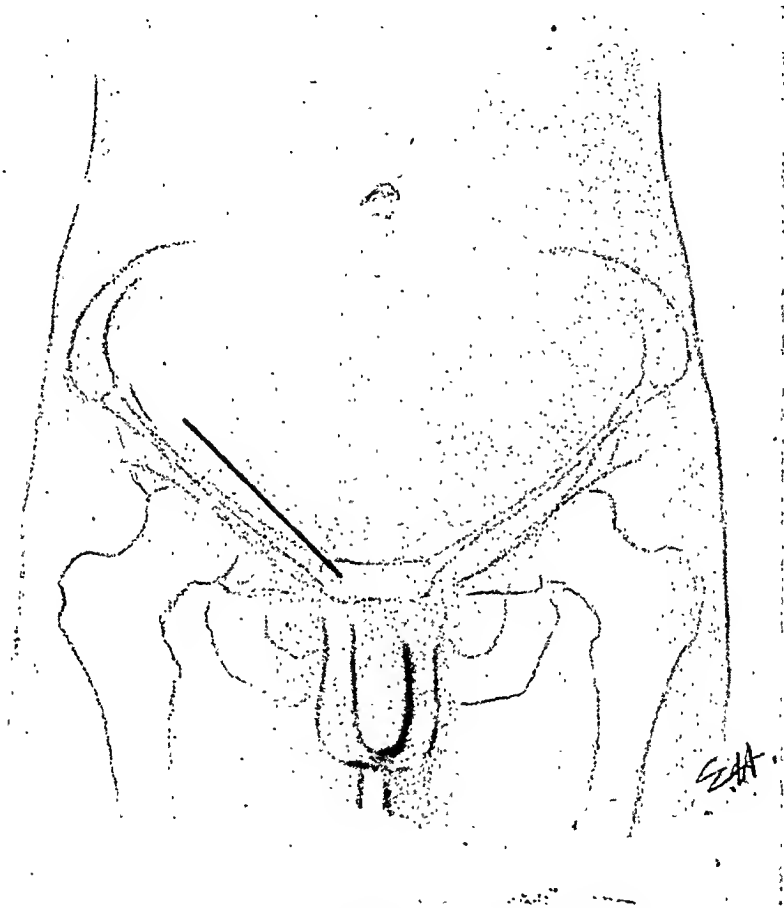


FIG. 1.—Showing the incision—extension of Bassini's incision over to the pubic bone.

rectus sheath. Similarly, the lower edge of the cut aponeurosis of the external oblique is dissected downward and outward to Poupart's ligament. The inguinal canal is thus exposed.

4. By blunt dissection with forceps, the neck of the hernial sac is easily identified. The sac is surrounded by the infundibuliform fascia, the cord with its vessels lying posteriorly and often adherent thereto.

5. The neck of the sac is held between forceps and opened, care being taken that there is no intestinal content in the sac, adherent or otherwise. The neck is resected, the cord and its vessels being carefully separated by blunt dissection.

6. The neck of the sac is thoroughly dissected so that the peritoneum around the neck of the sac is free from its superficial structures.

7. A curved needle is passed through the falx inguinalis about one inch above its lower border, guided by one finger placed through the neck of the sac into the peritoneal cavity, care being taken all the while that no part of the abdominal contents is injured in the process. The needle is brought out at the neck of the sac, and a purse-string suture is inserted around the neck and taken back to the muscle, guided by a finger in the abdominal cavity.

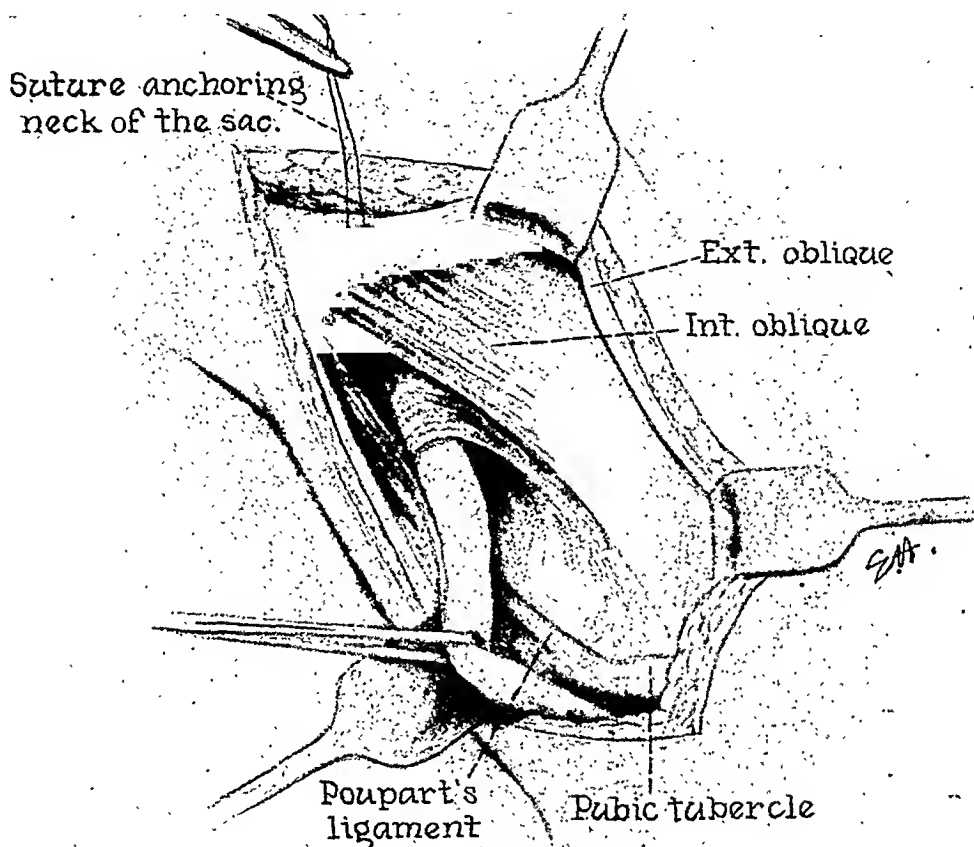


FIG. 2.—Exposed area ready for fascial graft implantation.

By tying this suture, the neck of the sac is closed and brought behind the muscle.

8. Poupart's and Cooper's ligaments and the pubic tubercle are well cleaned and exposed by blunt dissection. The outer border of the lower end of the rectus muscle, the inner surfaces of the same and the inner surface of the falx inguinalis up to Poupart's ligament are separated by blunt dissection from the deeper peritoneal and preperitoneal structures.

9. The cord is now grasped within a strip of gauze and held out of the way until the new bed is made for it.

10. The preserved ox fascia, about 2 x 1.5 inches, is dried of alcohol between gauze and placed on the area. One long border of the fascial graft is sutured to Poupart's ligament by four interrupted sutures. The lower corner is sutured to Cooper's ligament and the inferior border is fastened to the periosteum of the pubic bone, taking care to include a good part of the

periosteum. A slit is made about one-half inch in length on the upper border of the graft, and the cord is passed through this opening. A suture is passed through the falx inguinalis, while the muscle is being lifted by a retractor, continued through both corners of the slit ends of the graft, carried back through the muscle and tied. The fascial graft is thus anchored under the

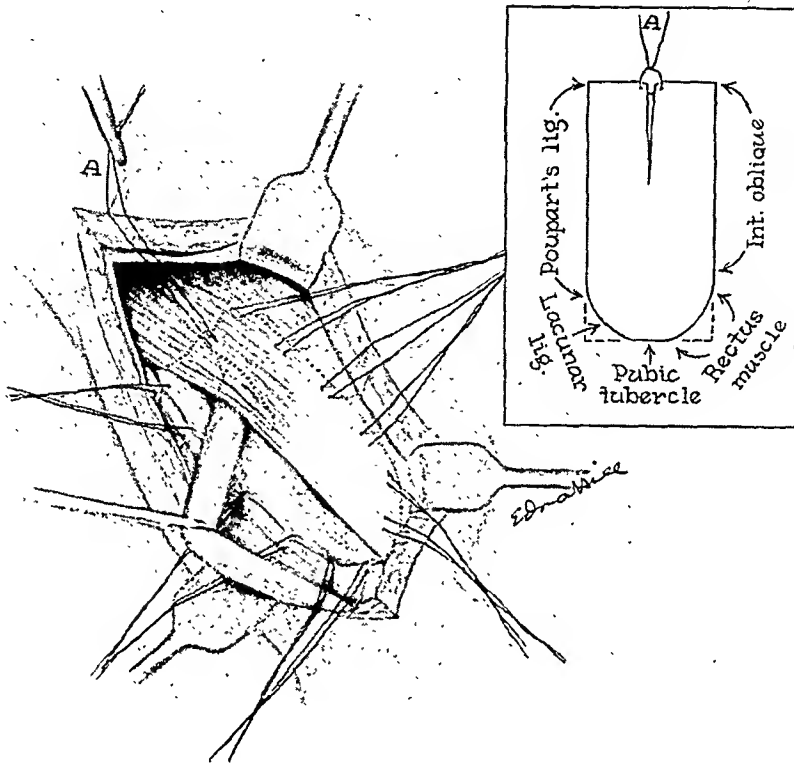


FIG. 3.—Fascial graft *in situ*.

falx inguinalis, allowing a passage for the cord. Two sutures are used to anchor the fascia under the conjoint tendon and two to secure the fascia under the rectus sheath on the medial side. Sometimes it may be necessary to slit a part of the rectus sheath to insert the fascial graft under that muscle. Now, the fascia is well anchored to Poupart's ligament, the pubic tubercle and under and to the falx inguinalis and rectus sheath, the cord passing through a narrow slit in the fascia.

II. The cut edges of the external oblique aponeurosis are next sutured and the wound is closed by interrupted sutures.

#### ANALYSIS OF A PERSONAL SERIES OF CASES\*

One hundred and fifty-eight consecutive cases of hernia have been repaired

\* I am grateful to Dr. P. W. Harrison, Bahrain, for his assistance and suggestions, as it was under his supervision that this work was carried out.



by the above method. No case was considered as unfit for operation because of old age, long duration of hernia, economic condition or any other cause. One hundred and four were indirect herniae, 46 direct herniae, and 8 were sliding herniae. Of these, 62 cases were over 50 years of age. One hundred and eight patients had herniae of five or more years' duration. Twenty-two patients had herniae of the size of a football, the largest extending to the level of the knees when the patient was standing.

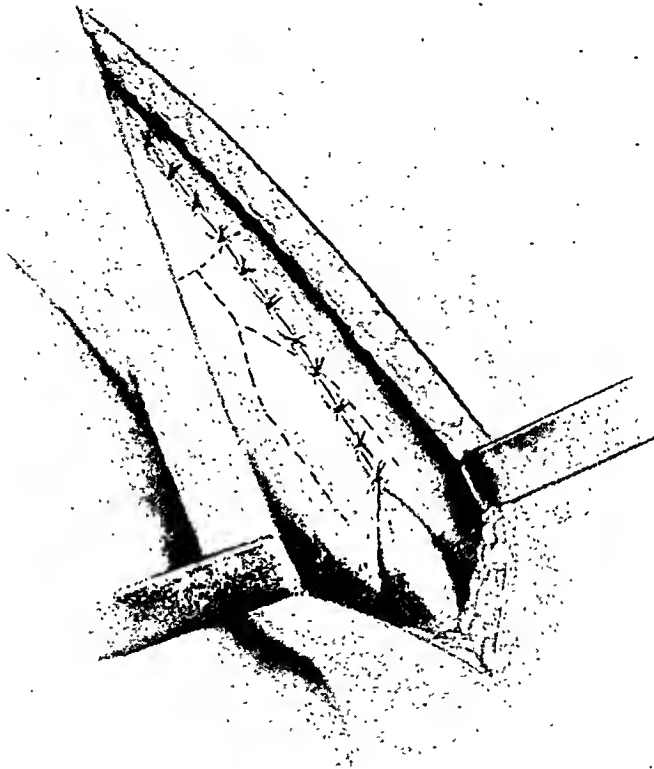


FIG. 4.—After the closure of external oblique fascia.

All of these 158 patients were discharged from the hospital within 7 to 12 days, the majority on the ninth day. Two patients had mild skin infection which healed within 5 to 8 days, thereby prolonging the hospitalization that many days. One of the patients had a strangulated hernia, and the other had had a previous skin infection at the site of incision. All of the patients were allowed to return to normal life and duties one week after discharge from the hospital, which was within three weeks of the time of operation.

The operations were performed in the Bahrain Mission Hospital, Persian Gulf, in an area where there is no other hospital equipped to do major surgery. The earlier cases were operated upon four years ago, and the most

recent one in this series 10 months ago. Fifty-three patients, most of whom were laborers, were employees of an oil company. Careful follow-up studies are being kept on them by monthly medical examinations, as they are still in the employ of the company. Among the others of this series, 79 were from the mainland of Arabia, or Persia, where there is no possibility of any treatment. The patients from these regions can only report to the Bahrain Hospital for their complaints. The remainder, 39 cases, were from the local island, and, as far as possible, a close follow-up was kept on them. Thus far there have been no recurrences.



FIG. 5.—Section of preserved ox fascia grafted in human tissue for four years shows good capillary growth at the periphery. A network of collagen fibers and fibroblasts has grown into the fascia, dividing it into bundles, the nuclei of the original fascial fibers having almost disappeared.

#### FASCIAL SURGERY

In 1910, Kirschner pointed out the fact that free fascial grafts could be successfully employed in the repair of herniae and introduced the method of hernioplasty. In 1921, Gallie and LeMesurier<sup>1</sup> reintroduced this subject. These authors employed strips of fascia lata from the thigh and used them as suture material to reinforce the weak posterior wall of the inguinal canal. In studying cases operated upon for recurrent inguinal hernia where an operation of the Bassini type had been performed, these observers found that in most cases no evidence of any previous muscle and fascia sutures remained. The same fact was also noted by Cudard and Jean<sup>2, 3</sup> in the following year. Large series of experiments were carried out by them and the following conclusions were reached:

1. Edge-to-edge suture of fascial wounds is not strong.
2. Overlapping does not add to the solidity of the scar.
3. Cleaned fascial surfaces unite better than when areolar tissue is left in between.
4. Side-to-side suture of the undamaged conjoined tendon to Poupart's ligament never leads to permanent union.
5. Living fascial strips become rounded and are soon organized as fine tendons.

In 1933, in his series of cases, Rives<sup>4</sup> formulated these conclusions:

1. Deprived of function, muscle atrophies.
2. Muscle offers no resistance to force perpendicular to its fibers.
3. Fascia is the ideal material for suturing.

So far, the multiplicity of operations for repair of herniae, and the differences of opinion regarding the mode of repair, showed that no one operation could be standardized as suitable to all conditions.

Later, in 1938, Harrison<sup>5</sup> advocated the use of preserved or living fascia intraperitoneally at the internal ring as a graft or patch without caring for the sac in the repair of herniae. Owing to the laxity of the peritoneum in old and recurrent herniae, there had been a few recurrences even with this method.

#### CONSIDERATIONS OF THE ANATOMY OF THE INGUINAL REGION IMPORTANT IN THE FORMATION OF HERNIA

The area of the inguinal region which is not protected by well-formed muscular layers and fascia, especially in a pendulous, flabby abdominal wall, is the site of hernia, either direct or indirect. In long-standing, large herniae, the internal and external abdominal rings are opposite to each other and the aponeurotic fibers of the external oblique, near to the pubic tubercle, are so much stretched and separated that they are very thin and have very poor strength. This is especially so because the direction of the fibers of the external oblique aponeurosis is nearly parallel with the inguinal canal, hence, the fibers can easily be separated and cannot give sufficient support to prevent hernia formation.

The lower border of the internal oblique muscle arches over medially and runs almost horizontally until it reaches the rectus sheath at the semilunar line. Together with the lower border of the transversus abdominis muscle directly beneath, it forms the muscle border (*falx inguinalis*), which forms the superior border of this weak area. Medially is the rectus muscle with its sheath and pubic bone, and inferiorly is the inguinal ligament which runs from the pubic tubercle laterally and upwards to the *falx inguinalis*. The internal ring and the Hesselbach's triangle occupy this area. Because of the presence of the cord and its coverings, the most poorly protected region is at the inferior medial angle.

After the hernia, either direct or indirect, has been present for some time, especially in old people with loss of muscle tonus, the local fascia which is

available for repair work is so poor that it cannot be of much value. It is no surprise then that cases of this nature form the large majority of recurrences.

#### RESULTS OF STANDARD PROCEDURES FOR HERNIORRHAPHY

From a number of the largest and best surgical clinics,<sup>6</sup> follow-up reports, based on actual examinations of all types of inguinal herniae for two years, show from 5 to 10 per cent of recurrences after operation for indirect hernia and from 15 to 35 per cent after operation for direct hernia.

From the above consideration of the surgical anatomy of the inguinal region, it becomes evident that the operation for the radical cure of inguinal herniae should be based on strengthening the above described weak area of the inguinal region. Since repair of this region without heterogenous materials was not successful, especially in long-standing, direct herniae, which constitute a large percentage of those that recur, a method of heterogenous fascial grafts in the radical operation for herniae was developed.

In this connection, the works of Nageotte and Sencert,<sup>8</sup> and Koontz<sup>7</sup> are important. They brought forth a new conception of the character of fibrous tissue. They found that after preservation in 70 per cent alcohol, ox fascia, upon introduction into the human body, is not absorbed, but remains permanently in place unmodified in thickness and size. Also, Hass<sup>9</sup> has shown by his extensive experimental work that dead and preserved fascia united with other living structures as rapidly and firmly as did live fascia. Hence, in these heterogenous grafts in the radical operation for herniae, the preserved ox fascia not only remains permanently in place but unites with the living structures *in situ*, thereby, giving more strength and permanency to the repair.

From an anatomic and physiologic standpoint, heterogenous fascial grafts in the radical operation for herniae offer a permanent cure, without recurrences. This procedure is applicable to all types of cases. The probable objection is the possibility of infection because of the introduction of the foreign body. With moderate care, there is no need for such a fear.

#### SUMMARY

A short history of operative treatment of herniae is presented, with particular reference to the use of fascia.

The work of Hass on the use of preserved ox fascia in the living dog has been extended to patients. Especially prepared ox fascia appears to heal solidly in human tissue.

An operation for repair of direct and indirect inguinal hernia based on this observation is described.

Experience in 158 cases, with follow-up observations on a series of 53 employees of a firm providing routine medical examinations at monthly intervals, is presented. There were no recurrences in this latter group after periods of observation ranging from ten months to four years. No recurrences were reported in the other 105 patients.

The author is indebted to members of the Staff of Harrison Department of Surgical Research, Schools of Medicine, University of Pennsylvania, for assistance in preparing this manuscript.

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## RENAL DECAPSULATION FOR TRANSFUSION OLIGURIA

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AND

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IN RECENT YEARS the incidence of unfavorable reactions after transfusions has shown a marked decrease. This is due to two factors: (1) more care in matching of the donor's blood with that of the recipient; and (2) the general adoption of the method of using citrated blood. This method permits the blood to be given slowly and thus prevents overloading of the circulation, which at times is a serious consideration. Unfortunately, however, unfavorable reactions still continue to occur, and, in all probability, will continue to occur from time to time.

The most serious of these are the hemolytic reactions, which are practically always due to incompatibility between the bloods of donor and patient. The incompatibility may be due to mistakes in grouping, or to intragroup differences, the factor most frequently responsible for the latter being the *Rh* agglutinin of Landsteiner and Wiener.

The symptoms of an hemolytic reaction may be so slight as to escape notice, or so severe as to cause almost immediate death. Sometimes several days may intervene between the transfusion and the onset of symptoms due to hemolysis, and these may then be laid to the condition for which the transfusion was performed and their true nature not recognized. On the other hand, manifestation of the disease may be laid to the remedy.

The first symptoms of a typical hemolytic transfusion reaction usually start during the injection of the blood. The patient may develop a chill, precordial oppression, fullness of the head, tingling sensations, pain in the lumbar region, flushing of the face, distention of the veins of the neck, restlessness, dyspnea, anxiety, vomiting, coughing and collapse. These may not be evident if the patient is under a general anesthetic. Whenever any of these symptoms are noted the transfusion should be stopped at once. If the patient withstands the immediate reaction he develops oliguria or anuria and icterus, and later passes into the stage of renal failure characterized by stupor, edema, convulsions, coma and death. A few cases of anuria following transfusions without evidence of hemolysis have been reported. In these cases the anuria may have been due to the condition for which the transfusion was done, or the hemolysis may have escaped detection.

It is generally accepted that the renal symptoms are due to the hemoglobin released from broken down erythrocytes. When this exceeds a certain concentration level in the blood it passes out through the kidneys damaging the kidney parenchyma, causing a spasm of the renal artery, and producing a blocking of the tubules. According to Baker and Dodds, when the urine is alkaline the hemoglobin remains in solution and passes through the kidneys without causing damage, but when the urine is acid the hemoglobin is con-

verted into acid hematin which blocks the tubules. On this basis Daniels, Leonard and Holtzman have suggested alkalinization of the patient before transfusion. It is interesting that as early as 1875 Ponfik suggested that renal insufficiency following transfusions was due to mechanical blocking of the tubules by blood pigment.

There have been very few postmortem studies on patients who have died because of hemolytic transfusion reactions. Examination of those who died immediately have shown multiple thrombosis. Those who died of uremia have shown swollen kidneys with dark-colored pyramids. Microscopically, the tubular epithelium shows degenerative changes and the tubules contain brownish pigmented material and pigment casts. Necrotic foci have been found in the liver and severe hemorrhagic and ulcerative changes in the colon.

In the typical case the prognosis is always serious, the mortality rate being about 50 per cent. Bordley collected 17 cases from the literature, of which 11 died, and Wiener states that Golding and Graef reported seven cases with three deaths. Daniels reported 13 nonoperative cases with seven deaths. Death may occur from the fourth to the 18th day.

As stated above, on detecting the first suspicious symptoms the transfusion should be immediately discontinued. Then every effort should be made to induce diuresis by intravenous injections of solutions of glucose and salt, and the urine should be alkalinized by administration of sodium lactate or sodium bicarbonate. If the patient fails to make satisfactory improvement under these measures a unilateral decapsulation of the kidney should be considered.

Decapsulation of the kidney has had its ups and downs through the years. It has been recommended and carried out for many conditions. At times it has ridden the wave of popularity and at other times has been in ill repute. In recent years it has been almost entirely discredited.

Very few reports of cases of renal decapsulation for oliguria and anuria following transfusion have appeared in the literature. Abeshouse collected three cases, all of which recovered, and we have been able to add one case from the literature, which terminated fatally.

Bancroft's case secreted one ounce of urine the first day after transfusion, one ounce the second day, and in the next seven days the largest amount secreted in any 24 hours was six ounces. Nine days after transfusion a decapsulation of both kidneys was done. The day following decapsulation she secreted 9.5 ounces of urine, and this increased every day until the fifth day when she secreted 51 ounces. She made a good recovery.

The case of Flo and Cummings was catheterized 12 hours after transfusion, and 200 cc. of black urine obtained. Then her urinary output was between 60 and 90 cc. for 24 hours for a week. Nine days after transfusion, when her condition was desperate, a unilateral decapsulation was done. In the first 24-hour period after operation she produced 211 cc. of urine; the next 24-hour period produced 625 cc. In the next 24-hour period marked diuresis started and continued until she made a complete recovery.

Ravich's case had two transfusions, using the same donor, given two

days apart. She had a typical hemolytic reaction, with severe oliguria. Three days after the second transfusion a unilateral decapsulation was done. In the first 24 hours after operation she voided 325 cc. of urine; during the second 24-hour period 1,500 cc. The third day postoperatively her output was 4,980 cc. The fourth day it was 5,200 cc., and she went on to make a good recovery.

Beraud's case developed hemoglobinuria the day after transfusion. By the third day she was anuric. This persisted until the sixth day after transfusion when decapsulation of the right kidney and nephrostomy were done. On the evening of the same day the urinary flow was established. The patient, however, died two days later.

The beneficial effects of decapsulation of the kidney have been ascribed to various factors: mechanical relief of intracapsular pressure; interruption and destruction of sympathetic nerve supply of the kidney, with resultant improvement in renal circulation and increased urinary secretion; development of a new collateral circulation; increased drainage of lymph from the denuded kidney surface; and nonspecific protein shock. The weight of evidence indicates that the two factors first mentioned are the most important. For a thorough discussion of all the aspects of decapsulation the reader is referred to an excellent paper by Abeshouse which was just recently published.

Decapsulation is not difficult to perform, and carries in itself very little risk to the patient. After exposure of the kidney through the usual lumbar incision the cortex of the kidney is delivered into the wound and a longitudinal incision made through the capsule. With the finger the capsule is easily lifted from the kidney substance all the way to the hilum and excised. It apparently suffices to perform the operation on one side only. An unilateral decapsulation, of course, carries much less risk than bilateral, but it can be conceived that under certain conditions a bilateral decapsulation may be indicated, possibly in two operations.

The seriousness of hemolytic transfusion reactions with oliguria or anuria and the scant attention that decapsulation of the kidney has received as a remedy for this condition prompt the following report:

**Case Report.**—A 33-year-old infantryman was wounded in action 12 December, 1944, and sustained compound, comminuted fractures of both lower extremities. A guillotine amputation was done through the right thigh at the junction of the lower and middle thirds and through the left leg six inches below the knee, and he was later shipped back to the Zone of Interior and admitted to a General Hospital 10 January, 1945. On 3 April, 1945, he had revision of both stumps, under spinal anesthesia. During the operation he received 500 cc. of blood of his homologous group. (The patient's blood was Group O and *Rh*-positive. The donor's blood was Group O and *Rh*-negative.) No untoward symptoms were noted during the transfusion except restlessness. Following operation his pulse was elevated and he was somewhat disoriented and perspiring freely. He was, therefore, given oxygen and intravenous normal salt solution containing sodium lactate. By the next morning he had not voided so he was catheterized and 120 cc. of brownish urine obtained. This was examined and found to be acid and contained ++++ albumen and numerous red blood cells. By this time his skin showed a tinge of icterus. The blood of the patient and that of the donor were again carefully examined and previous findings confirmed. Both donor and recipient were Group O; the recipient



was *Rh*-positive, the donor *Rh*-negative, and cross-matching showed no agglutination; furthermore, no cold agglutinins were demonstrated.

By the morning of 6 April, 1945, three days after his transfusion, he had secreted only 210 cc. of urine in all, 120 cc. of which had been obtained by catheterization the morning following transfusion and 90 cc. had been secreted during the last 48 hours. Urinalysis on this day was reported as follows: Color brown, character opaque, reaction alkaline, Sp. Gr. insufficient quantity, albumen + + + +, sugar negative, bilirubin negative, urobilign negative; microscopic examination numerous red blood cells, abundant amorphous matter, occasional large macrophage, occasional granular cast. His N.P.N. was 100 mg. per 100 cc., and his creatinin 2.7 mg. per 100 cc. The patient was edematous and very drowsy and confused, and was vomiting continuously. It was the opinion of all who saw him that he was becoming rapidly worse and would undoubtedly die unless diuresis could be induced in some way. Since a three days' trial of medical treatment, consisting of administration of normal salt and glucose solution intravenously and alkalization of the urine, had failed to check his downward course, it was decided to perform an unilateral kidney decapsulation without any further delay.

This was carried out under spinal anesthesia reinforced by local infiltration and sodium pentothal. Exposure of the kidney was very easy. The kidney was markedly swollen and darker in color than normal. On incising the capsule the cut-edges immediately separated widely, and kidney parenchyma bulged into the incision, demonstrating the greatly increased intracapsular pressure. The capsule was easily separated from the kidney with the finger and excised. The kidney was dropped back and the wound closed without a drain.

Following operation his improvement was dramatic. In the first 24 hours post-operatively he secreted 80 cc.; in the next 24 hours 368 cc.; in the next 24 hours 2,120 cc., and in the next 24 hours 5,010 cc. His edema rapidly cleared up with the onset of diuresis and his vomiting ceased. His confusion, however, persisted for about ten days.

Twenty-six days after his decapsulation he was in good condition. His blood pressure was 120/80; N.P.N. 37 mg. per 100 cc.; creatinin 1.9 mg. per 100 cc.; urine from both kidneys was normal. Differential renal function test showed both kidneys functioning equally and well—23 per cent P.S.P. in each in one-half hour.

#### CONCLUSION

There is some evidence that unilateral renal decapsulation is of benefit in oliguria following transfusion, but further study is needed to substantiate this.

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# THE USE OF FLUORESCENT WHEELS IN DETERMINING EXTENT AND DEGREE OF PERIPHERAL VASCULAR INSUFFICIENCY

## FURTHER OBSERVATIONS

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SINCE SUBMITTING the original work<sup>1</sup> describing this new approach to the study of vascular insufficiency, several additional observations have been made which make for a better understanding of the mechanism involved. It is the purpose of this communication to present these points. A subsequent article devoted to a careful evaluation of clinical results will be published in the near future from the Department of Physical Medicine, State of Wisconsin General Hospital. It may be stated here that these results uphold the method in both theory and fact, and attest to its predicted value.

## BRIEF DESCRIPTION OF THE TEST

It was discovered by the author, while engaged in an investigation of the various tests for degree and extent of peripheral vascular diseases, that employment of Lange's surface fluorescence technic<sup>2</sup> as a method of clearly demonstrating the ability of tissue to produce wheals in response to minor injury, resulted in an effective new approach to these conditions. It was also noted that this test was simple to perform, unequivocally readable, and the results could be stated concisely in a few words. Two methods of producing wheals were used with equally good results. The simpler one (superficial scratches) was recommended for clinical use, and the other (intra-dermal histamine injections) was preferred as a gross experimental method. Early clinical application proved very promising, and the subject was presented in the form of a preliminary report under the title: "Wheal-Fluorescence: A New Method of Evaluating Peripheral Vascular Diseases."

## FURTHER OBSERVATIONS

The histamine-wheal test has been the only practical clinical way of utilizing the known fact that wheal formation is specifically dependent upon the presence of adequate vascular flow. Experience has upheld the basic truth that absence of a wheal response to this substance indicates marked impairment of circulation. However, if this fundamental is adhered to, as it should be, the information obtained reveals only very gross circulatory deficiency, and, thus, presents an incomplete picture of the true extent and degree of the process. In attempts to eliminate this obvious weakness, significance has been variously attributed to observations of the wheal diameter; time of appearance; pseudopodia; and size of the accompanying flare. These corollaries, unfortunately, are undependable for their intended purpose, and

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serve only to vastly complicate the test and confuse its interpretation. The employment of Lange's surface fluorescence in conjunction with the histamine wheals rectifies this situation; for it not only eliminates the necessity for bothering with these corollaries, but also exposes their unreliability. In addition, the new method affords all the desired information in a different manner. The following observations serve to support these claims:

1. *Neither the diameter of the wheal, nor the presence of pseudopodia, is a reliable measure of vascularity. Instead, these factors seem to be more dependent upon the physical nature of the tissue at a given point.* We have observed this fact many times. In the best vascularized areas; e.g., on the thigh of the unaffected leg, well above any possible vascular involvement, fluorescence will often reveal the wheals to be small and without pseudopodia. Conversely, on the dorsum of an impaired foot, where the wheal is all but invisible under ordinary light, fluorescence will often show it to be large with many pseudopodia. The reason why the latter wheals are not visually obvious under ordinary light is because they are extremely shallow. This leads us to the second, and most important observation:

2. *Diminished wheal depth (revealed under fluorescence by a proportionate decrease in intensity) is shown to be a sensitive and constant indication of significant, but less critical degrees of vascular failure.* This phenomenon is difficult to observe without fluorescence, and has not heretofore been revealed in its true importance. The level of change is readily apparent under fluorescence, and clinical experience has proved its significance to be as stated. In theory, the reason for this phenomenon seems to be that in partially impaired areas the intravascular pressure is decreased, allowing a small collection of fluid to quickly counterbalance it and prevent further accumulation. This is borne out by the fact that poorly fluorescent wheals never become brilliant with the passage of time, but rather seem to stabilize at an incomplete level of intensity and remain static. The diameter of these wheals may be large if the density of the tissue at that point allows lateral spread without requiring undue pressure to accomplish it. This lack of resistance may be due to local anatomic differences in tissue density, or to the dehydration and loss of elastic tissue which goes with ischemia.

3. *Time of appearance of the wheal can, for practical purposes, be ignored.* In the performance of the test, all wheals are present within the time-interval necessary to complete the injecting (or scratching), darken the room, and allow the ultraviolet light to reach peak intensity. This is a matter of a few minutes. Nonfluorescent wheals do not become fluorescent with the additional passage of time. Furthermore, as most clinicians who have employed the old method realize, it is difficult, to impossible, to accurately record the times of appearance of a multitude of bilaterally placed, serially laid wheals.

4. *Flares, while perhaps of some value in indicating vascularity, add nothing to the new test.* They cannot be seen under ultraviolet light unless they are particularly gross, in which case they are only dimly visible through intravascular luminescence. In many cases, they are not easily defined and

measured because of pigmentation of the skin, inflammation, or disguising antiseptics. Furthermore, they may be totally absent in certain nerve degenerations or injuries, regardless of vascular flow.

DISCUSSION.—It is apparent then, that histamine-wheal-fluorescence greatly clarifies, simplifies, and expands the scope and accuracy of the basically valuable wheal method. It affords a way of clearly defining the entire clinically significant extent of organic vascular insufficiency, including the degree of its severity. It does so by presenting a clear-cut, easily interpreted demonstration of both deficiency and/or absence of whealing. Since whealing is part of the normal repair reaction, such deficiency and/or absence points to a proportionate loss of ability on the part of the affected tissue to repair itself following injury. These facts are upheld clinically.

However, histamine-wheal-fluorescence does not eliminate the disadvantages attendant on the use of histamine. Employment of this substance requires unnecessary time and equipment; is painful; potentially dangerous; and causes a forced tissue response in the required dosage. The additional discovery (J. L. N.) that simple surface scratches are just as effective, simultaneously abolishes all these undesirable factors, and greatly simplifies performance of the test. Scratch-wheal-fluorescence, following the known facts regarding the tissue response to injury,<sup>3</sup> is qualitatively identical to histamine-wheal-fluorescence. All factors parallel the grosser method on a smaller, but equally readable scale. Performance of both technics on the same patient at the same time proves this beyond doubt.

#### SUMMARY

It is the author's belief that the method described is the simplest; most accurate; most easily interpreted; and least time-consuming way to reveal extent and degree of organic vascular disease. Its basis in theory is clear-cut, and, clinically, it works. Due to the interest of the Department of Physical Medicine, State of Wisconsin General Hospital (and the fact that the author is now serving in the United States Navy overseas), the test has been turned over to them. They have had no difficulty either in its performance, or interpretation. The test is made on request from the Departments of Surgery, Medicine, and Orthopedics, and the recorded results simply state the level of intensity change and/or absence of fluorescence in the scratch marks. The clinician is thus given the following information:

1. Whether or not significant organic vascular disease is existent.
2. If so, how severe it is, and how far it extends up the leg. These facts are used to aid in diagnosis, prognosis, and treatment; they reveal the presence or absence of improvement under conservative measures, and indicate the level where amputation (if necessary) will be attended by prompt healing.

#### CONCLUSIONS

1. Wheal fluorescence (both scratch and histamine) is a valuable new method in the study of peripheral vascular diseases.

2. Fluorescent scratch wheals are recommended for routine clinical use; fluorescent histamine wheals are preferred for experimental studies.

3. There are only two observations necessary to answer the problem of peripheral vascularity; *i.e.*, *presence*, and *depth* (*intensity*) of whealing. All other corollaries (wheal size, time of appearance, pseudopodia, flares) are either undependable, or unnecessary.

4. Previous predictions regarding the clinical applicability of the test are upheld.

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State of Pennsylvania } ss.  
County of Philadelphia }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Ellis W. Bacon, who, having been duly sworn according to law, deposes and says that he is the Treasurer of the ANNALS OF SURGERY and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

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[Seal]

HARRY J. BEARD.

(My commission expires March 5, 1949.)

# BRIEF COMMUNICATION

## THE INTRODUCTION OF RUBBER GLOVES FOR USE IN SURGICAL OPERATIONS

· JAMES F. MITCHELL, M.D.

WASHINGTON, D. C.

THE INTRODUCTION OF RUBBER GLOVES for use in surgical operations can without doubt be attributed to the late Dr. William S. Halsted, of the Johns Hopkins Hospital, in Baltimore. However, the exact time at which operating surgeons first wore them has been somewhat indefinite. Dr. Halsted,<sup>1</sup> in 1891, says "the assistant who passes the instruments wears thin rubber gloves. The only hands which come in contact with the wound are those of the operator. The sponging is done by the operating room nurse who wrings dry the sponges one at a time as they are required. The pieces of gauze used for sponging are kept in a solution of corrosive sublimate 1-1000."

Dr. Halsted,<sup>2</sup> in 1913 wrote as follows: "In the winter of 1889 and 1890—I cannot recall the month—the nurse in charge of my operating room complained that the solution of mercuric chlorid produced a dermatitis of her arms and hands. As she was an unusually efficient woman, I gave the matter my consideration, and one day in New York requested the Goodyear Rubber Company to make, as an experiment, two pairs of thin rubber gloves with gauntlets. On trial, these proved to be so satisfactory that additional gloves were ordered. In the autumn, on my return to town, the assistant who passed the instruments and threaded the needles was also provided with rubber gloves to wear at the operations. At first, the operator wore them only when exploratory incisions into joints were made. After a time the assistants became so accustomed to working in gloves that they also wore them as operators and would remark that they seemed to be less expert with the bare hands than with the gloved hands. I think it was Dr. Bloodgood, my house surgeon, who first made this comment, and that he was the first to wear them, invariably, when operating.

"In the report which I made of the first year's work at the hospital, written in November and December, 1890, and published in March, 1891, I stated that the assistant who passed the instruments wore rubber gloves. This assistant was given the gloves to protect his hands from the solution of phenol (carbolic acid) in which the instruments were submerged rather than to eliminate him as a source of infection. I do not recall having referred again, in my publications, to the employment of rubber gloves. Dr. Hunter Robb,<sup>3</sup> in 1894, in his book on 'Aseptic Surgical Technique' recommended that the operator wear rubber gloves. Dr. Robb was, at that time, resident gynecologist of the Johns Hopkins Hospital and had frequent opportunities to observe the technic of the Surgical Clinic.

"This incidental reference by Robb in 1894 to the wearing of rubber gloves, and the fact that a photograph of an operation for breast cancer taken late in the year 1893 shows that gloves were not being regularly worn by us at that time, serve to establish approximately the date of their definite introduction.

"Thus, the operating in gloves was an evolution rather than an inspiration or happy thought, and it is remarkable that during the four or five years when as operator I wore them only occasionally, we could have been so blind as not to have perceived the necessity for wearing them invariably at the operating table.

"It is also noteworthy that none of the many surgeons, foreign and American, who visited our clinic in those years should have recognized the desirability of eliminating the hands as a source of infection, by the wearing of



FIG. 1.—A photograph of the first surgical operation in which the operator wore rubber gloves. (Reproduced from a photograph made in 1893 by Dr. James F. Mitchell)

- |                          |                        |                   |
|--------------------------|------------------------|-------------------|
| 1. James F. Mitchell     | 3. Joseph C. Bloodgood | 5. John (Orderly) |
| 2. Chauncey Pelton Smith | 4. Harold C. Parsons   | 6. Sidney Cone    |

gloves. We did not realize how slightly the sense of touch is obtunded by the rubber covering or how unessential it is in most operations that the greatest delicacy of finger perception be preserved."

Dr. Robb's only reference to gloves is that "the danger can be easily avoided by protecting the hands with rubber gloves, which have been soaked in 1-500 aqueous solution of bichloride of mercury before being used."

The general adoption of gloves aroused some controversy. Dr. Robert T. Morris,<sup>4</sup> in 1898, says: "I have been much interested in everything that seemed to be in the nature of progress in surgery . . . but have arrived at the conclusion that the practical disadvantages of gloves counterbalance their theoretical advantages. Surgeons who were doing first class work three years ago seem to me to be doing second or third rate now, on account of the interference made by their gloves. The greatest danger to be feared is that the younger generations of surgeons may fail to develop the sense of touch to the highest degree and we shall have much second rate work done, particularly in abdominal surgery . . . to the younger generation of surgeons I say fight with

your might against the idea of using a means that will damage your most precious possession—the sense of touch.”

McBurney,<sup>5</sup> in the same year, was most emphatically in favor of their use, stating that he began using gloves in 1897. By this time the operator, assistants and nurses in Dr. Halsted's clinic were all wearing gloves in every operation. Dr. Bloodgood,<sup>6</sup> in 1896, describes an operation for hernia performed by him on September 15, 1896, in which the operator and assistants wore gloves. This, however, was by no means the first instance in which the operator wore gloves, as is attested by the accompanying photograph (Fig. 1). This represents the first operation in which gloves were worn by the operator: hence the reason for making the photograph. The date can be definitely fixed by the fact that one of the assistants was Dr. Chauncey P. Smith, of Buffalo, who was assistant resident in Surgery from June, 1893, to June, 1894, and the operation was probably performed in the summer of 1893. Unfortunately, the nature of the operation is not known. It will be noticed in the photograph that there were no caps, gowns or masks worn then. I entered the Johns Hopkins Hospital as head nurse in Dr. Halsted's operating room in June, 1893. At that time the cleansing of the hands was very strenuous. First, the hands and arms were scrubbed with green soap for five to ten minutes; then dipped in a saturated solution of potassium permanganate reaching above the elbows; then dipped in a saturated solution of oxalic acid and then soaked in a 1-1,000 solution of bichloride of mercury, for five minutes. As a result irritated and cracked hands and arms were not infrequent, at times so severe as to keep the sufferers out of the operating room for many days. The instruments were boiled for ten minutes and then submerged in a solution of five per cent carbolic acid. From this it was the duty of the head nurse to distribute them in glass dishes containing a two and one-half per cent carbolic acid solution and sometimes to pass them to the operator. I, therefore, wore gloves from June, 1893, except when acting as an assistant at the operating table. When I began to operate, and ever since, I have always worn gloves, and the sense of touch has been developed from the first through gloved hands, as is the case with practically all younger surgeons of today.

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# THE USE OF BLOOD PLASMA FOR FILLING THE PLEURAL SPACE FOLLOWING TOTAL PNEUMONECTOMY\*

A CLINICAL STUDY

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SINCE GRAHAM'S<sup>1</sup> successful removal of an entire lung for bronchogenic carcinoma in 1933, surgical treatment of this tumor has enjoyed marked success. In a recent article by Rienhoff,<sup>2</sup> who reviewed his own series of 181 consecutive cases, and reported on the results of a number of other surgeons, it was found that the mortality for this operation has been reduced to an average of 20 to 25 per cent, and in some instances as low as .66 per cent. Most of the technical difficulties of the procedure have been overcome, the principle causes of fatality being some form of infection or cardiorespiratory failure. A fairly high percentage of patients with this lesion are in the sixth or seventh decade of life. Therefore, a marked lowering of reserve in the cardiorespiratory function is present. Thus, in these patients an infection that otherwise might be relatively unimportant may be sufficient to result fatally.

In Graham's first patient, following the removal of the lung, a seven-rib thoracoplasty was made for obliteration of the pleural space. This was performed for a number of reasons, not the least of which was to avoid the danger of a serious empyema. Subsequent experience has demonstrated that total ablation of one lung may be performed without thoracoplasty, and that a serosanguineous fluid coming from the adjacent tissues fills the residual cavity. At the present time most pneumonectomies are made without thoracoplasty, although the procedure of choice continues to be controversial.<sup>3</sup> The chief objections to pneumonectomy without thoracoplasty have been: (1) the hazard of serious infection of the pleural space and mediastinum; and (2) the ill effects produced by overexpansion of the remaining lung. A third, and seldom considered undesirable effect of this method, is the lowering of the blood plasma protein and tissue protein reserve, which is partly due to the filling of the remaining pleural space with fluid rich in proteins.

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\* This work was supported in part by a grant from the Douglas Smith Foundation for Medical Research of the University of Chicago.

The rate of filling this space following pneumonectomy is quite variable, depending upon the vascularity of severed adhesions, and the amount of operative trauma. It may be quite rapid, especially where sulfonamides are used locally in the pleural cavity at the site of operation. The rate of filling is probably also increased by the negative pressure in the pleural cavity.

The accumulated pleural fluid has been analyzed and found to contain approximately 4 to 5 Gm. per cent of proteins, somewhat less than that normally contained in blood plasma. Since this space usually has a capacity of between 700 and 1,000 cc., the amount of proteins removed from the circulating blood and, thus, from the protein reserve of the tissues is considerable. The degree of ill effects of rapid depletion of proteins from the circulation and tissue reserve will depend upon (1) the status of tissue proteins preceding operation; and (2) the adequacy of replacement of blood loss during and following the surgical procedure. Although at the present time there is a better appreciation of the severity of blood loss accompanying intrathoracic operations, recent studies have indicated that these patients do not usually receive sufficient replacement therapy for maintaining the blood in the pre-operative status.

The ill effects of hypoproteinemia on the surgical patient have been investigated in recent years. Extensive studies on both animal and man reveal a striking parallel between the incidence of postoperative infections and delayed healing of wounds, and the presence of subnormal blood proteins. Thompson, Ravdin and Frank<sup>4</sup> produced hypoproteinemia in dogs and found that the repair of wounds was delayed in these animals. In further experiments<sup>5</sup> delayed healing was averted by the restoration of blood proteins to a normal level immediately following operation.

In a study of postmortem material, including both medical and surgical conditions, Cannon, and his associates,<sup>6</sup> showed a definite relationship between protein deficiency and the incidence of serious infection. The explanation for this was found in the lowered concentration of antibody globulin in protein deficient rats, demonstrated by immunologic and chemical methods.<sup>7</sup> In further investigations on rabbits they found that a diminution of agglutinins produced an increased susceptibility to infection in the presence of hypoproteinemia as compared to litter mates with normal blood protein levels.

In view of the hazard of infection in the pleural cavity following pneumonectomy and its relationship to protein deficiency, at the suggestion of Doctor Phemister, some experiments were planned to test the effect of filling the pleural space with blood plasma following the removal of an entire lung in animals.<sup>8</sup>

In experiments performed on 61 dogs and four goats, complete blood studies were made before and after the resection of an entire lung. In one group no transfusions were given following the operation, and the pleural cavity was allowed to become obliterated spontaneously. In the second group, replacement of blood cells and plasma lost both during operation, and

into the pleural space following operation, was made by the transfusion of plasma or by whole blood. In the third group, the replacement therapy was entirely made by the use of blood plasma or serum which was placed in the pleural cavity at the end of the operation. The results of the control experiments revealed that the total blood proteins were reduced by as much as 25 to 30 per cent of their preoperative value. This reduction placed the blood proteins at a significantly low level of 4 to 5 Gm. per cent, and the preoperative level was not regained for approximately ten days, the period of wound healing. Several factors were thought to be contributory in producing the reduction of proteins, namely, removal of lung tissue, the thoracotomy wound, infection, and the lack of nitrogen balance.

Replacement therapy in the form of blood or serum given intravenously, or serum intrapleurally, was quite effective in reducing the amount of blood protein fall after pulmonary resection. If given in sufficient amounts, both methods of administration appeared to be quite effective.

In view of the above results it was decided to make a clinical study of the changes in blood proteins following various operations on the thorax.<sup>9</sup> Blood protein determinations, made by the micro-Kjeldahl method,<sup>10</sup> and hematocrit values were obtained before and at two-day intervals for a ten- to 14-day period after 32 major operations including: lobectomy, 14; pneumonectomy, five; exploratory thoracotomy, seven; and miscellaneous, six. From these investigations it was found that the blood plasma proteins fell approximately 1 Gm. per cent following these operations, and occurred in 31 of the 32 instances. This fall occurred in spite of the fact that the blood lost at operation was thought to have been fairly adequately replaced. The range of fall for the 14 lobectomies was from 0.44 to 2.91 Gm. per cent, the lowest blood protein level usually being on the fourth or fifth day following operation. In approximately one-third of the entire series of 32 patients the fall was below the danger level of 5.50 Gm. per cent. The average transfusion for this group of patients was 942 cc. at operation and an additional 782 cc. during the period of convalescence. The fall in protein level was ascribed to operative blood loss, loss of blood and serum into the wound and pleural cavity following operation, infection, diminished protein reserve, and inadequate replacement therapy. Transfusion of whole blood was thought to be the most satisfactory single therapeutic agent when blood proteins were lowered due to loss of blood.

In view of the results of the above studies, it was thought worth while to test the influence of filling the pleural space with plasma following total pneumonectomy in man. This report is based on results obtained in 18 patients receiving such treatment, and ten additional patients used as controls in whom no plasma was employed. The usual method of management was as follows: Prior to operation the red cell count, hemoglobin value and plasma protein level were determined. If preoperative transfusions were required the tests were repeated following the transfusion. At the time of surgery between 500 cc. and 600 cc. of blood plasma were introduced into the pleural

TABLE I  
ALTERATION OF THE BLOOD FOLLOWING TOTAL PNEUMONECTOMY—USE OF PLASMA FOR FILLING THE PLEURAL SPACE  
Blood Studies

Case and Init.	At Operation		Days Postoperative												Remarks
	Plasma in Pl. Cav.	Blood Transfusion	1	2	3	4	5	6	7	8	9	10 to 15			
1 C. C.	0	Preop. R.B.C. 4.5 Hb. 14.0 P.P. 13.0											No infection.		
2 H. R.	0	R.B.C. 4.8 Hb. 12.0 P.P. 10.0						4.3 13.0					No infection. Died 9 mos. PO of ruptured appendix and peritonitis. Died 6 days PO of heart failure. No infection.		
3 P. Q.	0	R.B.C. 4.6 Hb. 12.0 P.P. 14.0			5.0 14.0		4.5 14.0								
4 S. S. L.	0	R.B.C. 4.2 Hb. 16.0 P.P. 13.0	4.4 14.0			4.1 13.0				3.5 14.0		4.3 13.5	Died 5 wks. PO of infection of pleural and pericardial cavities.		
5 T. F.	0	R.B.C. 4.6 Hb. 12.0 P.P. 13.0		5.2 13.0		4.9 15.0				5.5 15.0	4.9 12.0		Died 11 days PO. Pneumonia, bronchial fistula with empyema.		
6 R. T.	0	R.B.C. 4.9 Hb. 15.5 P.P. 7.4	4.4 14.4	4.9 13.5	4.0 13.1	4.6		4.4 6.4	4.4 16.0		4.2		Pleural fluid protein = 4.1—4.3 Gm. %.		
7 J. K.	0	2650 cc. R.B.C. 4.8 +500 cc. Hb. 12.5 Plasma P.P. 6.4	5.0 16.5	4.8 13.0	4.8 5.9	4.5 14.3		5.9 16.0	5.9 16.0	6.9		5.1 14.0	Bronchitis and atelectasis. Died 13 days PO of sulfa-anuria.		
8 L. R.	0	9 days PO R.B.C. 3.8 1000 cc. Hb. 11.0 +300 cc. plasma P.P. 6.8	4.9 12.0	5.5 12.0	5.4 12.0	5.0 11.5	5.2 6.2	4.1 6.4	4.0 13.0	4.0 6.1		4.2 6.6	Pleural fluid protein = 4.2—4.7 Gm. %. Pleural fluid protein = 4—4.3 Gm. Bronchial fistula and empyema. Thoracoplasty.		
9 M. K.	0	Sulfathiazole 1500 cc. R.B.C. 4.2 2.5 Gm. Hb. 12.5 P.P. 6.2	4.1 14.0					4.2 13.5					Pleural fluid protein = 4.4 Gm. %. Bronchitis and atelectasis. Pneumonia.		
10 A. H.	0	1500 cc. R.B.C. 5.0 Hb. 15.0 P.P. 7.2	4.9 16.4		13.8 5.3	4.6 13.8	5.02 14.1			14.2		4.8 15.0	Stormy PO course, with bronchial secretions and pneumonitis.		



TABLE I—(Continued)  
ALTERATION OF THE BLOOD FOLLOWING TOTAL PNEUMONECTOMY—USE OF PLASMA FOR FILLING THE PLEURAL SPACE  
Blood Studies

Case and Init.	At Operation		Preop.	Days Postoperative										Remarks
	Plasma in Pl. Cav.	Blood Transfusion		1	2	3	4	5	6	7	8	9	10 to 15	
22 P. C.	600 cc. +400 cc. 3 days PO 200,000 P.	1000 cc. +1000 cc. 9 days PO	R.B.C. 4.5 Hb. 13.0 P.P. 7.1	4.7 13.5			4.2 11.5 5.9					4.1 12.8 5.7	3.3 11.8 6.1	No infection.
23 F. K.	550 cc. +450 cc. 4 days PO 200,000 P.	1000 cc.	R.B.C. 5.0 Hb. 13.5 P.P. 7.4	4.9 13.0 7.3		5.1 13.5 6.0	5.3 14.0 6.4				4.5 13.0	4.4 12.0 6.6		No infection.
24 J. N.	550 cc. +250 cc. 4 days PO 200,000 P.	1500 cc. +500 cc. 8 days PO	R.B.C. 4.5 Hb. 11.0 P.P. 5.6	4.9 13.5						12.5	4.7	4.5 10.5 5.1		No infection.
25 M. B.	550 cc. 200,000 P.	1000 cc.	Hmt. 33.2 R.B.C. 4.8 Hb. 13.2 P.P. 6.4	41.0 4.3 13.0	39.8 4.3 13.0	40.4	4.3 12.3	39.5	4.7	3.8 12.3	38.4	4.3 13.0		Pleural fluid protein = 4.6 Gm. %.
26 H. W.	550 cc. 200,000 P.	1000 cc.	Hmt. 40.2 R.B.C. 4.9 Hb. 13.8 P.P. 7.2	41.3 4.7 12.4			37.7			36.3				Died 3rd day PO of bronchial asthma and cardiac failure. No infection.
27† A. C.	550 cc. 200,000 P.	1500 cc.	R.B.C. 4.8 Hb. 13.0 P.P. 7.7	4.8 13.5 7.0		4.9 13.5 8.0	7.2				4.6 13.0	4.4 13.0 7.4		No infection.
28 O. S.	550 cc. +250 cc. 1 day PO 200,000 P.	1500 cc.	R.B.C. 4.8 Hb. 12.6 P.P. 7.4	4.8 13.6		4.9 13.6		5.0 7.1						Pl. fluid prot. = 4.95—5.21 Gm. %. Died. 5 days PO of bronchial pneumonia. Vital capacity 1700.

Detailed results of blood studies before and following total pneumonectomy in 28 cases.

The complications and blood determinations on pleural fluid are indicated under remarks.

Abbreviations: R.B.C. = Red blood cells.

Hb. = Hemoglobin.

P.P. = Total blood plasma proteins.

\* This patient had an arteriovenous fistula of the left lung for which total pneumonectomy was performed.

† This patient had a chronic diffuse pneumonitis for which a total pneumonectomy was performed.

cavity at closure of the thoracic wall. In addition to the plasma, 200,000 units of penicillin were placed in the pleural space in nine of the 18 patients.

Between one and three days after operation, following chest fluoroscopy, the remainder of the residual air was removed and replaced with plasma, usually 200 to 400 cc. Immediately following operation and for a period of two to three weeks, additional analyses of the blood were made at intervals of one to three days.

In addition to the above studies, fluid was obtained for plasma protein determinations, culture, and penicillin concentration from the pleural cavity in both the control and the treated groups.

### RESULTS

Detailed results of these studies are seen in Table I. In analyzing this data one should keep in mind that an attempt had been made, in most patients, to replace the entire amount of estimated blood lost at operation by blood transfusion during and immediately following the operation. For this reason surgical shock was practically never observed.

From the data presented, and also from studies as yet unpublished,<sup>11</sup> it was evident that the greatest drop in red cell count, hemoglobin and hematocrit occurred between the third and fifth day after surgery. Following this there was a slow return to normal, but in most instances the preoperative plasma protein level had not been reached by the end of two weeks postoperatively.

The lowering of blood plasma proteins was also usually greatest by the third to fifth day but the fall did not always parallel that of the hemoglobin. In some patients the red cell count and hemoglobin remained very nearly the preoperative level, although the plasma proteins fell. (See Cases Nos. 7 and 16.) When the proteins were lowered to a considerable degree, *i.e.*, by 1 to 1.5 Gm. per cent, they usually had not returned to the preoperative level by the end of two weeks following operation.

Table II and Graph I present the changes in blood plasma proteins following pneumonectomy. The range of lowest level of proteins following operation is indicated in A of Table II, the largest number of patients averaging between 5 and 6 Gm. per cent. However, three patients in Group II did not fall below 6 Gm. per cent.

The range of plasma protein fall following surgery is indicated in B of Table II. Nine of the 14 treated patients (Group II) fell less than 1.4 Gm. per cent, two others were between 1.4 and 1.7 Gm. per cent. The three remaining patients (Nos. 13, 15 and 16) all received sulfathiazole locally in the pleural cavity at the time of operation. This resulted in a marked accumulation of pleural fluid. In patient No. 16, 680 cc. were removed to relieve a serious mediastinal shift. In patient No. 13 a large amount of serum drained out through the chest wound. The third patient had inadequate replacement of blood loss by transfusion. Thus, there is adequate explanation for the marked lowering of plasma proteins in these three cases. In the control group (I) the fall in plasma proteins ranged from 1 to 2.1 Gm. per cent, none of

TABLE II

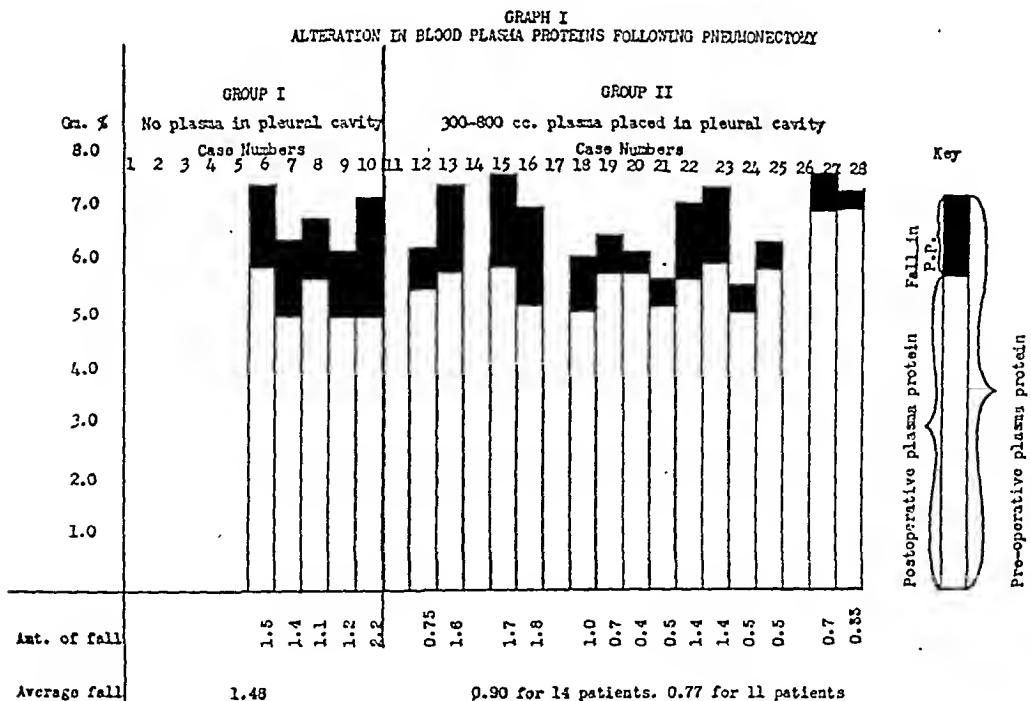
## BLOOD PROTEIN ALTERATION FOLLOWING PNEUMONECTOMY

Blood Plasma Protein Fall Following Operation	Group I No Plasma Placed in Pleural Cavity	Group II Pleural Cavity Filled with Plasma
A. Range of lowest level of plasma proteins:	Patients—	Patients—
5.0—5.4 Gm. %	Total and Case Nos.: 3 (7, 9 & 10)	Total and Case Nos.: 4 (16, 18, 21 & 24)
5.5—5.9 Gm. %	2 (6 & 8)	7 (12, 13, 15, 19, 20, 22 & 25)
6.0—6.4 Gm. %	0	1 (23)
6.5—6.9 Gm. %	0	0
7.0—7.4 Gm. %	0	2 (27 & 28)
B. Range of fall of plasma proteins:	Total and Case Nos.	Total and Case Nos.:
0.3—0.5 Gm. %	0	5 (20, 21, 24, 25 & 28)
0.6—0.9 Gm. %	0	3 (12, 19 & 27)
1.0—1.3 Gm. %	2 (8 & 9)	1 (18)
1.4—1.7 Gm. %	2 (6 & 7)	4 (13*, 15†, 22 & 23)
1.8—2.0 Gm. %	0	1 (16‡)
Over 2.0 Gm. %	1 (10)	0
C. Avg. fall	1.48 Gm. %	0.9 Gm. % for 14 patients 0.77 Gm. % for 11 patients (See below)

\* Patient No. 13 had a tumor of the chest wall two inches in diameter removed in addition to a pneumonectomy. Patient also received 5 Gm. of sulfathiazol in the pleural cavity and drained considerable fluid from the chest wound.

† Patient No. 15 had inadequate replacement by transfusion in addition to receiving 5 Gm. of sulfathiazol in the pleural cavity which produced an increased pleural effusion.

‡ Patient No. 16 received 5 Gm. sulfathiazol in the pleural cavity which resulted in marked pleural effusion—680 cc. being removed to correct for mediastinal shift.



GRAPH I



the patients falling less than 1 Gm. per cent, which is similar to the findings in the previous study made of this problem. The average fall for the 14 patients who received plasma in the pleural space was 0.90 Gm. per cent. However, if the three patients above mentioned are eliminated the average fall was 0.77 Gm. per cent. In contrast to this, the average fall for the control group was 1.48 Gm. per cent or almost twice that of the 11 treated patients.

The postoperative level as well as the fall in plasma proteins is indicated on Graph I. It is readily seen that a high percentage of the treated patients had only a slight lowering of the plasma proteins and maintained a higher postoperative level than the patients in Group I or the controlled series.

The complications following operation are listed in Table III. The incidence of serious complications and the mortality rate were almost twice as

TABLE III

POSTOPERATIVE COMPLICATIONS FOLLOWING TOTAL PNEUMONECTOMY IN 28 PATIENTS

Group I—Pleural cavity allowed to fill with fluid spontaneously. (10)

Complications:

1. Cardiac failure, 1
2. Sulfonamide anuria, 1
3. Bronchial fistula, 2
4. Empyema, 2
5. Bronchitis and atelectasis, 4
6. Pneumonia, 1

Deaths, 4:

1. Cardiac failure, 1
2. Sulfonamide anuria, 1
3. Infection, 2\*

\* One death occurred 5 weeks following operation (2.5 weeks after returning home).

Group II—Pleural cavity filled with blood plasma. (18)

Complications:

1. Cardiorespiration failure, 1
2. Pulmonary embolism, 2
3. Pneumonia, 1
4. Bronchial fistula, 1 (temporary—no infection)
5. Empyema, 1

Deaths, 4:

1. Pulmonary embolism, 2
2. Cardiorespiratory failure, 1 (bronchial asthma)
3. Pneumonia, 1 (V. C. 1700 cc. before pneumonectomy)

great in the control group as in the group which received plasma in the pleural space following resection of the lung. Although this series of patients is not large, the discrepancies between the two groups is significant. One of the most striking differences is the high incidence of infection of various types in the control group as compared to the treated patients. Factors influencing this feature are considered in Table IV where the patients are classified according to the method of closure of the bronchus, the use of penicillin, and the use of plasma intrapleurally following operation. The method of closing the bronchial stump has varied somewhat from time to time. However, the first group in which closure was made by two rows of sutures, the proximal being mattress in type, after the method described by Overholt, were not necessarily the first operations performed. Some of the patients in Group II in which closure of the bronchial stump was made with a single row of interrupted sutures over the end of the stump were among the earliest resec-

tions made. A large percentage of the operations in Group II were the most recently performed, using only a single row of sutures for closing the bronchial stump. This fact must be taken into consideration in interpreting the low incidence of complications in this group.

TABLE IV  
RESULTS FOLLOWING TOTAL PNEUMONECTOMY IN 28 PATIENTS CLASSIFIED ACCORDING TO TYPE OF  
BRONCHIAL CLOSURE AND THE USE OF PLASMA AND PENICILLIN IN THE PLEURAL CAVITY

	No. of Cases	Complications						Deaths
		Atelec- tasis	Pneu.	Emp.	Fist.	Pul. Emb.	Card. Fail.	
I. Closure of bronchial stump with two rows of sutures								
a. No plasma in pleural cavity.....	7	2	1	3	2	0	1	4 { 1—Fistula & emp. 1—Card. failure 1—Empyema and pericarditis 1—Sulfonamide anuria
b. 300 to 600 cc. plasma in pleural cavity.....	5	0	0	1	1	1	0	1—Pulmonary embolism
Total.....	12	2	1	4	3	1	1	5
II. Closure of bronchial stump with one row of sutures								
a. No plasma in pleural cavity.....	3	1	1	0	0	0	0	0
b. 500 to 800 cc. plasma in pleural cavity.....	4	0	0	0	0	1	0	1—Pulmonary embolism
c. 550 to 1000 cc. plasma and 200,000 U. penicillin in pleural cavity.....	9	0	1	0	0	0	1	1 { Cardiorespiratory failure (bronchial asthma) Bronchial pneu. 1 { (V.C. 1700 cc. preop.
Total.....	16	1	1	0	0	1	1	3

The highest incidence of complications and greatest mortality was found in Group Ia where two rows of sutures were used for closing the bronchus. When plasma was placed in the pleural space in addition to the above method of bronchial closure the incidence of complications was considerably lowered (see Ia and b). The lowest incidence of complications was obtained in Group II-C where the bronchial stump was closed with a single row of interrupted sutures and the patient received plasma and penicillin intrapleurally following operation. Of the nine patients, one had bronchial asthma, and died of pulmonary insufficiency following operation. Another patient had a vital capacity of only 1,700 cc. before operation and died on the fifth postoperative day of what appeared to be bronchial pneumonia. This patient was receiving 120,000 to 160,000 units of penicillin daily in addition to 200,000 units in the pleural cavity. There was no infection on the side of operation. There were no other complications in this group.

A striking difference in the incidence of postoperative empyema and bronchial fistula was seen between the two methods of bronchial closure.

Of the 12 cases closed by the two row suture technic, four developed an empyema, three of which had a bronchial pleural fistula. In contrast with this, none of 16 patients whose bronchial stump was closed by the single row suture technic developed either an empyema or fistula following operation. The remaining complication, namely, pulmonary embolism, was observed twice in the entire series of 28 cases, and was fatal in each patient. One occurred in each type of bronchial closure. The etiology for this complication was not demonstrable.

DISCUSSION.—In a clinical study such as this, where a number of variables are unavoidable, it is difficult to accurately interpret the influence of the various factors on the results obtained. In addition to the data presented, one other factor was present in all patients except Nos. 1 and 2, namely, oral or intravenous administration of sulfonamides before and following pneumonectomy. In view of the fact that this therapy was used practically throughout the series, it is probable that it did not play a rôle in the discrepancy of results between the control and treated groups of patients.

The results of the blood studies, including the plasma proteins, reveal that for the most part the blood loss during and following operation was not completely replaced by transfusion although it was our intention to do so; further that the plasma protein level could not be predicated by the blood count and hemoglobin values.

Although the operative wound practically always healed by primary intention (exception—Case 13), the incidence of pneumonia, bronchitis, atelectasis, and empyema were twice as frequent in the control group of patients as in the group in which the pleural space was filled with plasma. Just how much the increased lowering of the plasma proteins in the control group contributed to the increased incidence of infection is difficult to say. In view of the fact, as has been pointed out earlier, that infection and delayed wound healing showed a striking parallel to subnormal blood plasma proteins in experimental studies, it is at least suggestive that a relationship existed between the two.

At postmortem examination on two patients expiring three and five days after pneumonectomy (Nos. 26 and 28) the bronchial stumps were securely closed and covered by a very firm layer of fibrin. This fibrin also extended into the fluid of the pleural cavity, the major portion of the latter having been placed there at the end of operation. It would seem reasonable to believe that a continual bathing of the region of the bronchial stump with plasma might contribute to the maintenance of its closure following surgery. In addition, the plasma as a vehicle for the penicillin simultaneously placed in the pleural cavity would carry the penicillin to all parts of the cavity in a concentration sufficient to ward off active infection resulting from unavoidable contamination at the time of operation. The results in the nine patients in which this was done would bear out this reasoning since in no patient was there infection in the pleural cavity following the removal of the lung on that side. This was true in spite of the fact that in one patient death due to bronchial pneumonia occurred five days after surgery (Case 28).

## SUMMARY AND CONCLUSIONS

The influence of filling the pleural space with plasma following total pneumonectomy was studied in 18 patients and the results compared with those in ten control patients.

Blood studies made before and after operation showed less lowering of the plasma proteins in the treated group (average of 0.77 Gm. per cent as compared to 1.48 Gm. per cent in the control patients). More significantly, the blood proteins in the treated patients were in general maintained at a higher level than those of the control group (5.8 Gm. per cent as compared to 5.3 Gm. per cent).

The incidence of complications following operation, including empyema, bronchial fistula, bronchitis, atelectasis and pneumonia, was much less in the group of patients whose pleural space was filled with plasma, being approximately 50 per cent of that of the control group.

The influence of subnormal blood and tissue proteins on wound healing and the development of infections is discussed.

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# CHRONIC LEPTOMENINGEAL THICKENING FOLLOWING TREATMENT OF MENINGITIS WITH SULFA-DRUGS

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SINCE THE INITIATION of serum therapy of meningococcic meningitis various neurologic defects have been recorded as sequels to otherwise successful treatment of the infection. Among these may be mentioned infantile hemiplegia or diplegia, paraplegia in adults, deafness and deaf mutism, and aphasic troubles, but the most common late complication is chronic hydrocephalus. As the infection is overcome the purulent exudate is organized by proliferation of fibroblasts which occlude the narrow pathways in the leptomeninx and obstruct the circulation of the cerebrospinal fluid. It might have been expected that the same train of events would follow the suppression of a suppurative meningitis by sulfa-drugs or penicillin. Lately we have observed numerous examples.

## CASE REPORTS

Case 1.—J. H., a male, age 16, was admitted, November 14, 1944, because of repeated convulsions.

In August he developed an earache. On August 29 the right ear drained spontaneously. Sulphathiazole was administered on August 30 and on August 31 a right mastoidectomy was performed. On September 7 he had a high fever and stiff neck with severe headache. A lumbar puncture secured cloudy fluid containing 1523 leukocytes per cu. mm. and numerous gram-positive cocci. Cultures of the fluid remained sterile. On October 4 the spinal fluid contained 1240 leukocytes but, again, no growth was obtained from the fluid. Aside from continuous administration of sulphadiazine 75,000 units of penicillin were given intraspinally in nine separate doses of 5,000–10,000 units between September 7 and October 25. By October 12 his temperature was normal but a week later he became suddenly much worse, was irrational and uncoöperative and his temperature rose to 104° F. On October 23 a lumbar puncture obtained cloudy fluid with 29,500 cells. He began to have convulsions and was admitted to the Institute.

He was irrational with a temperature of 103° F. The right pupil was larger; there was a ptosis of the left upper eyelid and a right facial paralysis. His neck was stiff.

He was given sedatives to quiet him and 100,000 units of penicillin intramuscularly, but his temperature rose steadily and he expired the following morning.

Necropsy disclosed a left acute otitis media, an early interstitial pneumonia, a partially healed right mastoidectomy wound, and passive congestion of the spleen and adrenal glands. *Alpha* streptococci were grown from the base of the brain and *gamma* streptococci from the left middle ear.

On external inspection of the brain one saw a milky thickening of the leptomeninx over the base and extending up the lateral fissures toward the vertex. The ventricles were not dilated but the ependyma was juicy, yellowish and cloudy; the left temporal horn appeared to contain a small amount of pus.

Microscopic examination disclosed here and there in the leptomeninx small abscesses and clumps of macrophages filled with débris. Aside from the small abscesses the predominant infiltrative cells in the leptomeninx were lymphocytes and plasma cells with an

occasional polymorphonuclear leukocyte (Fig. 1). The most striking feature, however, was the unusual proliferation of fibroblasts with the production of vast numbers of connective tissue fibrils.

The ventricles were the seat of an acute purulent infection with an inflammatory exudate consisting predominantly of polymorphonuclear leukocytes.

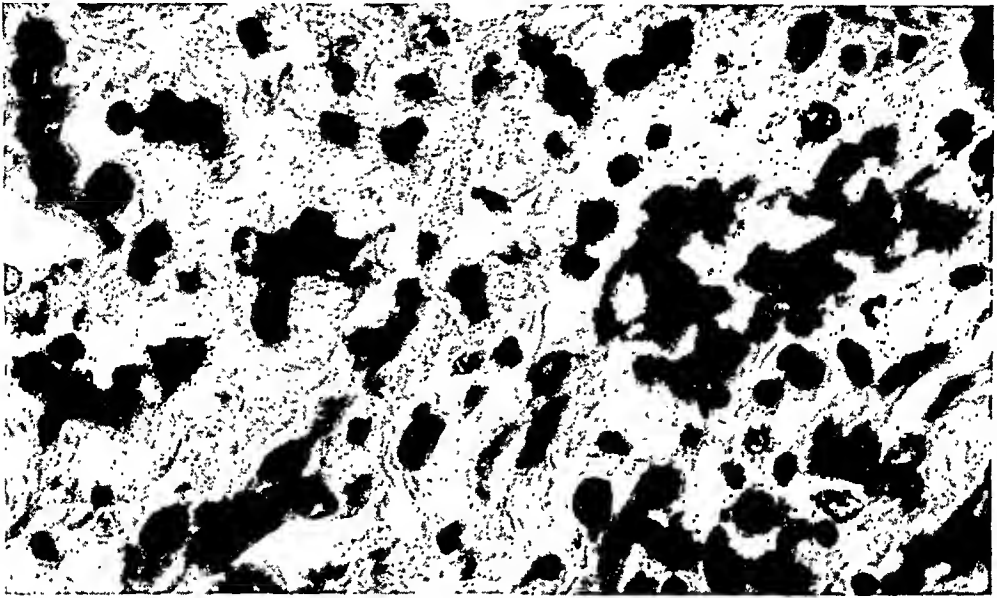


FIG. 1.—Case 1: Unusual proliferation of connective tissue fibrils forming a network in the meshes of which are entangled lymphocytes, plasma cells and an occasional polymorphonuclear leukocyte.

COMMENT: The meningitis seemed to be well on the way to healing. The sudden increase of symptoms leading to death would seem to be due to an extension of the infection to the ventricular system.

Case 2.—L. di J., a female child, age 11, was admitted November 18, 1942. Born normally, she had been well, except for measles at the age of seven, until August 1942 when she developed a severe headache. Because she had a fever she was given sulphathiazole for some time, how much is not known, and improved somewhat but later became worse and was taken to an hospital where a lumbar puncture was made on October 17. The initial pressure was 115 mm. of water. There was an increased cell count, mainly polymorphonuclear leukocytes, the actual count being unknown. On November 5 another puncture is said to have found increased pressure, the fluid was turbid and contained 9,000 cells, 80 per cent polymorphonuclear leukocytes. Cultures of the fluid were negative. She was then given sulphadiazine, how much is unknown, and her fever returned to normal but she became unresponsive.

When admitted to the Institute her temperature was 101° F. by rectum but promptly dropped to 99.6° and thereafter fluctuated around 100° until near her death when it reached 104°. She was emaciated and dehydrated. The leukocyte count in the blood was 8,250. She could be roused with difficulty to respond with a feeble cry and to answer questions briefly. Her neck was slightly stiff. There was a bilateral Kernig sign and bilateral Babinski signs. The ear drums were normal. The optic disks were slightly blurred but not elevated. Both external rectus muscles were paretic.

A lumbar puncture obtained slightly turbid fluid with a count of 500, mainly polymorphonuclear leukocytes. Cultures of the fluid were negative. On December 8 there were still 600 cells in the fluid. Cultures were again negative and injected guinea-

pigs remained healthy. Wassermann tests were negative on the blood. Mantoux test was negative.

On December 11 a ventriculogram was made and disclosed only generalized dilatation of the ventricles.

She became slowly more stuporous and expired January 31, 1943. Necropsy disclosed a patchy bronchopneumonia, cloudy swelling of the kidneys, liver and adrenal glands, hemorrhagic cystitis and fatty degeneration of the liver. *Gamma streptococci* were grown from the leptomeninges.

The brain was of normal size but the markings of its inferior surface were obscured by a whitish thickening of the leptomeninx of the basilar and posterior cisterns. This pathologic alteration did not appear to extend to the lateral or interhemispheric fissures. There was a moderate internal hydrocephalus. The interventricular foramina and the aqueduct were not obstructed.

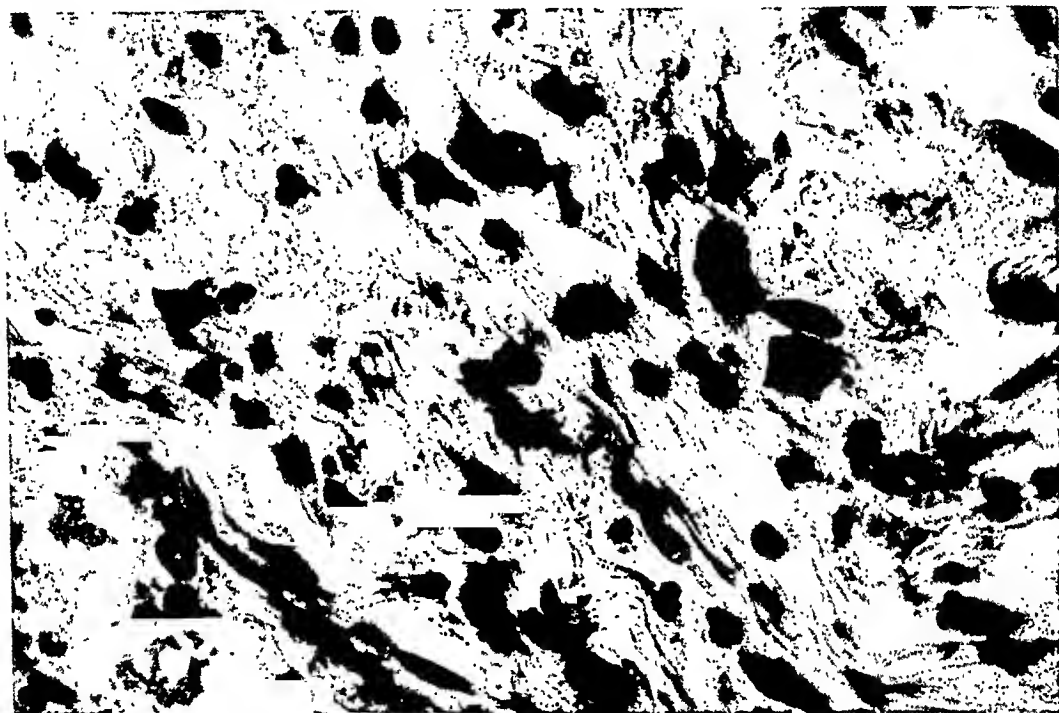


FIG. 2.—Case 2: Leptomeningeal infiltration containing scattered polymorphonuclear leukocytes but great numbers of flourishing fibroblasts.

Microscopic preparations revealed the thickening of the leptomeninx to be due to a marked fibroblastic proliferation from the walls of the numerous vessels. In addition, there were foci of chronic inflammatory reaction, consisting mainly of lymphocytes and plasma cells but with numerous polymorphonuclear leukocytes. No tubercle bacilli and no other pathogenic organisms were found. The fibroblasts were flourishing, forming broad bands of fibrils (Fig. 2).

COMMENT: Again, the infection had been checked but not destroyed, and the thickening of the leptomeninx had already begun to produce an hydrocephalus.

Case 3.—D. A. H., a male child, age four months, was admitted August 10, 1943.

Of normal birth, he was breast-fed and well until he was one month old, at which time he developed a high fever. A diagnosis of meningitis was made and the child was treated with sulfanilamide. On July 12 his temperature was 102° F., his neck was stiff and the fontanel bulging. Lumbar puncture obtained cloudy fluid, with 12,735 leukocytes and 14 mg. per cent of sulfanilamide. He was then given 30 cc. antimeningococcus serum

intravenously and sulfadiazine was begun. On July 14 his sulfadiazine level in the blood was 41.1 mg. per cent; in the ventricular fluid 63 mg. per cent. On July 26 the spinal fluid contained 1,673 cells. Cultures of the spinal fluid on several occasions were always negative. His temperature subsided to normal by September 25, but he remained stuporous.

When admitted, the child's head was retracted and measured 49 cm. in circumference. The anterior fontanel was widely open and bulging. The cranial sutures were separated. He was emaciated and dehydrated. His temperature was 103° F. on admission but subsided promptly to around 99°. The ear drums were normal.

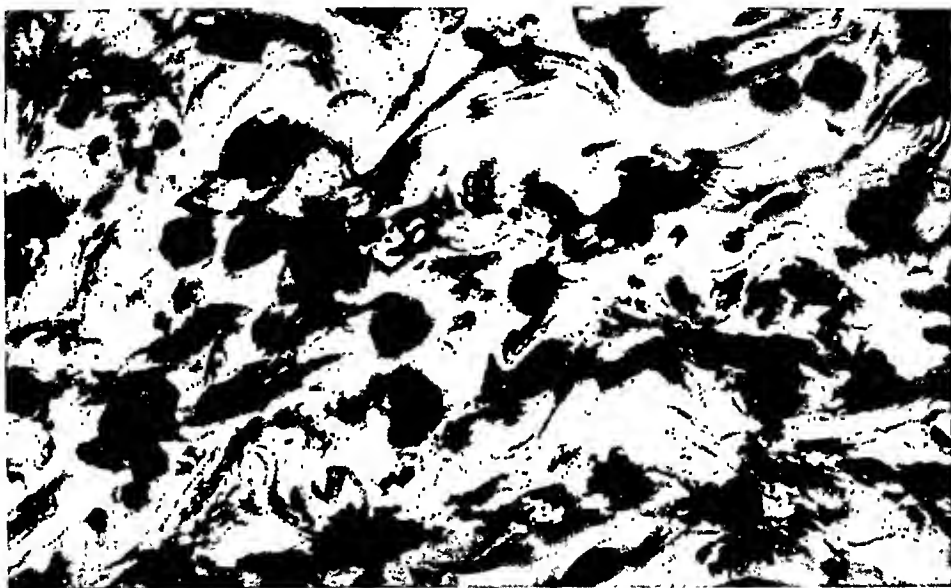


FIG. 3.—Case 3: Vast tangle of robust fibroblasts with an occasional macrophage.

A roentgenogram of the skull showed dilatation of the sutures. On August 24 the lateral ventricle was punctured and air was injected, demonstrating a wide general dilatation of the ventricular system. The ventricular fluid contained seven lymphocytes per cubic centimeter and nothing was cultured from it. Following this procedure the temperature rose to 106° F. but promptly fell and remained around 99° until the child's death on October 20.

Necropsy disclosed an early bronchopneumonia. No organisms were grown from the brain or meninges.

The cerebral hemispheres were enormously dilated and the cortex greatly thinned. The interventricular foramina and the aqueduct were widely dilated. There was a large opening through the septum pellucidum. There was a marked whitish thickening of the leptomeninges over the entire base of the brain, extending upward along the lateral and interhemispheric fissures but less evident over the vertex.

On microscopic examination, the thickening was found to be caused principally by an enormous proliferation of fibroblasts and capillary blood vessels (Fig. 3). A great many macrophages, containing blood pigment, were present but only a few inflammatory cells, mostly lymphocytes and plasma cells. There were no tubercles and no giant cells. Tubercle bacilli were not found. Within the parenchyma of the brain only the changes due to the hydrocephalus were found.

COMMENT: In this case the infection seems to have been eradicated but the hydrocephalus steadily increased.



Case 4.—R. S., male, age 15, was admitted January 6, 1945. He was well until December 6, 1944, when he complained of pain in the back. On December 7 he had a chill and headache. December 10 he was taken to an hospital where he was found to have a fever of 102.8° F. and a stiff neck. The spinal fluid was cloudy and contained 10,000 leukocytes per cu. mm. Cultures of the fluid remained negative after 48 hours. He was given sulfadiazine, five to six grains per day, and 200,000 units of penicillin within the next 48 hours. His temperature rose to 105°. On December 13 he was given 100,000 units of penicillin, intraspinally, in two doses of 50,000 each. The sulfadiazine was changed to sulfathiazole, 30 grains four times daily. Penicillin was again given; by December 16, 300,000 units had been given. On that day he had several convulsions. December 17 a transfusion of 400 cc. blood was given and, on December 21, another. On December 23 the patient had difficulty in moving his legs. December 25, no

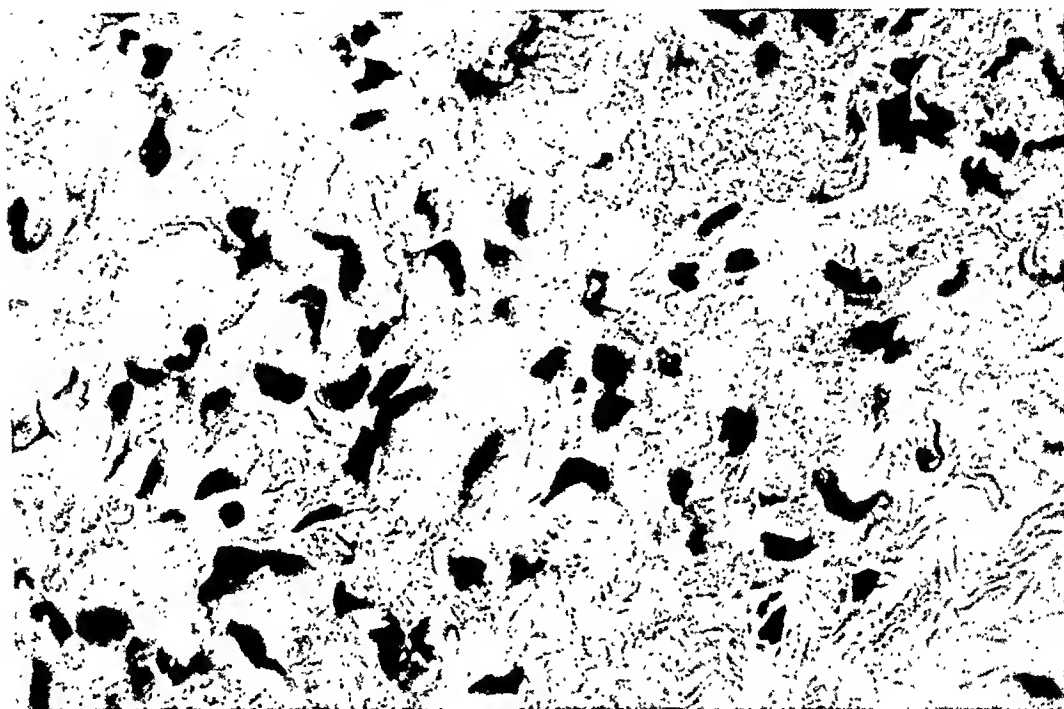


FIG. 4.—Case 4: Leptomeninx consists of a dense scar of collagenic connective tissue.

fluid could be obtained by spinal puncture; both legs were now paralyzed. On January 6 he was transferred to the Institute.

His temperature was normal. He had a completely flaccid paraplegia, with loss of both tendon and superficial reflexes and a positive Beever's sign. There was anesthesia to all forms of sensation over the sacral dermatomes and hypesthesia up to D<sub>10</sub>. He was incontinent of urine.

Lumbar puncture was made at various levels up to D<sub>8</sub> but no fluid was obtained. On January 9 a laminectomy was performed at D<sub>7-8-9</sub> under local anesthesia. The dura mater was lightly adherent to the arachnoid membrane. The subarachnoid space was completely obliterated and the spinal veins thrombosed. A biopsy was made of the greatly thickened leptomeninx.

The wound healed promptly and he was discharged, condition unchanged, January 25, 1945.

Examination showed that the leptomeninx had been transformed into a dense scar of collagenic tissue. Inflammatory cells were entirely absent (Fig. 4).

COMMENT: This case demonstrates the end-stage of an inflammatory exudate which predominated in the spinal region.

## SUMMARY

In all of these cases the course of events was much the same: an acute purulent infection which was controlled or cured by administration of sulfa-drugs or penicillin but the condition went on to death or some serious sequel. The disabling sequels are largely the result of the fact that these drugs exert no restraining influence on the fibroblasts which proliferate enthusiastically in their attempts to organize the exudate. The result is the transformation of the leptomeninges into a dense scar through which the cerebrospinal fluid cannot circulate and the contraction of which may constrict blood vessels and pathways essential to proper functioning of the nervous system.

It is not suggested that these drugs be not used in the treatment of suppurative leptomeningitis but a plea is made for early diagnosis and intensive therapy before a massive exudate has occurred and it is suggested that in any case the prognosis should be very guarded.

# RADICAL RESECTIONS OF ADVANCED INTRA-ABDOMINAL CANCER

SUMMARY OF RESULTS IN 100 PATIENTS\*

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IN RECENT YEARS, advances in the supportive treatment for surgical patients have reduced the risks attendant upon major operative procedures. These supportive measures include the prevention and treatment of shock by liberal use of blood and plasma, especially the former, refinements in anesthesia, especially the introduction of continuous spinal, greater appreciation of the importance of fluid and electrolyte balance and the general nutritional status, and the introduction of chemotherapy, especially for pulmonary and urinary complications.

Measures for the reduction of mortality also permit of the extension of operative surgery in situations which although regarded as technically possible, in the past, were considered beyond feasibility because of the belief that the patients would not survive.

During the past few years the writer has performed radical or massive resections in 100 patients with abdominal malignant tumors, which, by the usual criteria, were in the advanced stage. The literature includes a number of reports of very radical resections of abdominal cancer carried out in individual or small groups of patients but insofar as could be determined there have been no published studies of the possible benefits of such surgery in a significant series. Immediate survivals alone in isolated instances, interesting as these might be, would not justify advocacy of a general extension of operative attack upon advanced intra-abdominal cancer when effective palliation might be envisaged by the more conservative short-circuiting operations if obstructions of one type or another existed.

Since no two patients present identical situations comparative studies are impossible; furthermore, such studies cannot include "controls" as in the case of laboratory experiments upon animals. Moreover, "five-year survivals" in patients with advanced abdominal cancer, as a rule, can hardly be envisaged. The results, therefore, must be expressed in terms of palliation received. This is difficult to evaluate properly since a surprising degree of palliation may obtain by conservative measures. For example, not of the least importance, is an interested and encouraging attitude on the part of the attending physician, with judicious use of sedation. Great emphasis on maintaining a good nutritional state in the patient is also of paramount importance. Relief from pain and

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\* The records of these case histories were facilitated by the O. C. Miller Fund for Cancer Research of the University of Chicago.

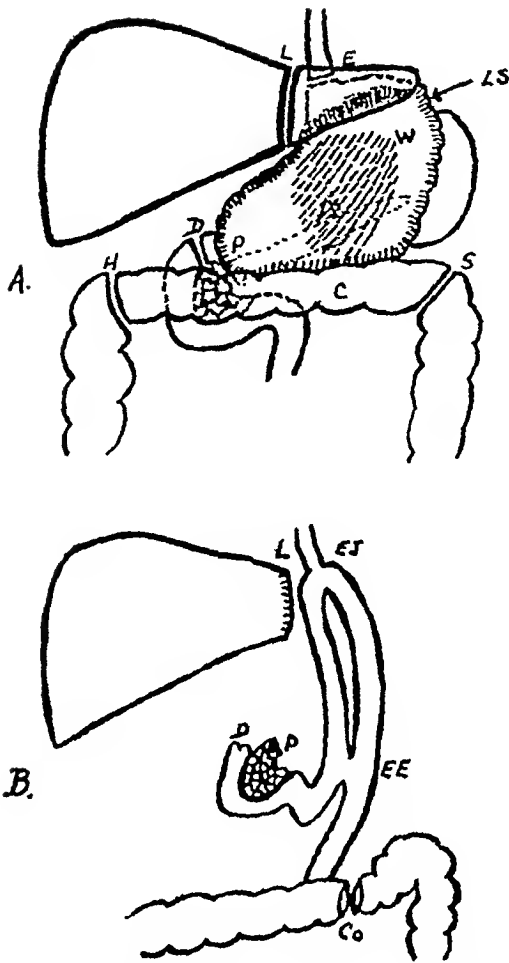


FIG. 1A.—Case 1 (339809): (A) Diagram showing levels of transection: (L) base of left lobe of liver; (E) esophagocardiac junction; (D) pylorus; (H) hepatic flexure; (S) splenic flexure; (P) neck of pancreas; (LS) large lymphosarcoma replacing practically all of stomach; (W) abdominal wall musculature and deep fascia invaded by tumor and excised *en masse* with the neoplasm.

(B) Situation at the close of the operation; (L) stump of liver after resection of left lobe; (EJ) esophagojejunostomy; (EE) entero-enterostomy; (D) invaginated duodenal stump; (P) transected neck of pancreas; (CO) colostomy, hepatic to splenic flexures.

Resection of large round cell sarcoma primary in and practically replacing the entire stomach with spread to neighboring organs and tissues. The entire stomach, half of left lobe of liver, body and tail of pancreas, spleen, left adrenal, transverse colon, entire omentum and abdominal wall in the left upper quadrant were excised *en masse*; double-barrel colostomy, hepatic end of ascending colon to splenic end of descending colon through stab wound to one side of midline incision (Fig. 1).

Result: Survival for over two months with ability to relish food eaten and appreciable relief from pain. Died of rapidly progressing generalized sarcomatosis, the period of deterioration lasted for only two weeks.

Case 2.—F. W. (No. 328218). Male, age 68.

Resection *en masse* of entire stomach, entire pancreas, entire duodenum, left adrenal, spleen and entire omentum for carcinoma of the body of the pancreas directly invading the posterior wall of the stomach, with metastases to nodes along lesser curvature and in greater omentum.

adequate regulation of nutrition, may result in remarkable gain in weight. Relief of obstructions alone, even in advanced stages of abdominal cancer may on occasion afford appreciable palliation for an unanticipated period. Those who have followed carefully patients with slowly advancing cancer are also aware of the powers of suggestion and psychotherapy in obtaining for certain periods, at least a sense of well-being.

The patients considered in this series presented varying types of neoplasms with varying degrees of metastases and local extensions. Thus, the series of operations is an heterogeneous one indeed, and in almost every instance was not a standard procedure but one devised to the situations encountered. Limiting consideration to the endeavors of a single operator serves to control such factors as minutiae of technic, surgical judgment, manual dexterity, etc.

A definition of what constitutes radical or massive resections of advanced abdominal cancer is difficult to formulate. The following are examples:

#### CASE REPORTS

Case 1.—E. B. (No. 339809). Male, age 28.

# ADVANCED INTRA-ABDOMINAL CANCER

Result: Survived three and one-half months. Relief from pain and jaundice for two and one-half months. (Previously reported in greater detail.<sup>1</sup>)

Case 3.—P. H. (319547). Male, age 49.  
Resection *en masse* of entire sigmoid colon, dome of urinary bladder, terminal half of left spermatic cord, abdominal wall (except skin and superficial fascia) in left lower

FIG. 1 (Cont'd)

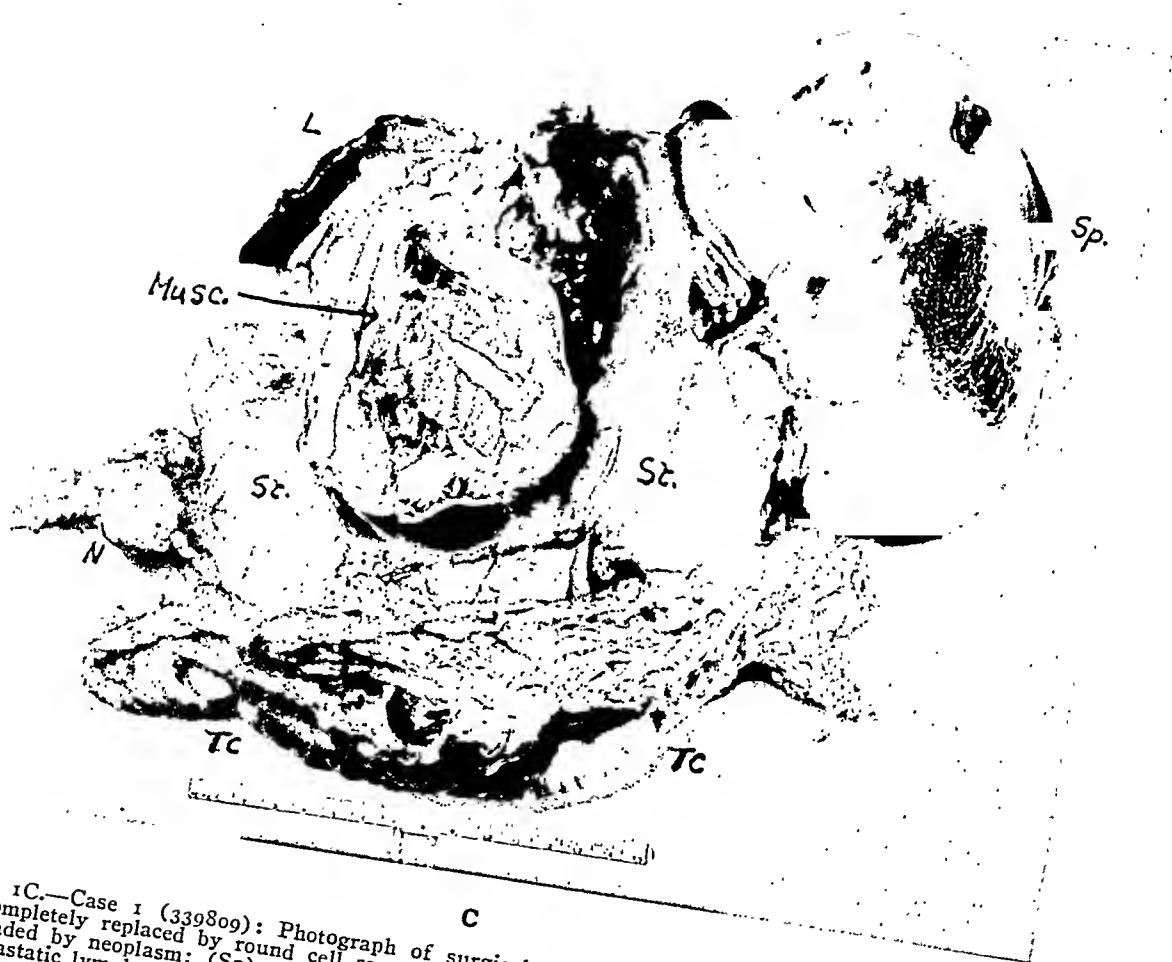


FIG. 1C.—Case 1 (339809): Photograph of surgical specimen consisting of (St) entire stomach almost completely replaced by round cell sarcoma primary in fundic portion; (L) half of left lobe of liver invaded by neoplasm; (Sp) spleen; (TC) entire transverse colon and contracted omentum; (N) large metastatic lymph node from over head of pancreas; (Musc.) musculature, deep fascia and anterior parietal peritoneum from left upper quadrant of anterior abdominal wall invaded by tumor. The body and tail of pancreas, and left adrenal gland were also resected but are not seen here as they are on the reverse aspect of the specimen. Operation completed by esophagojejunostomy, jejujejunostomy and double-barrel colostomy (hepatic end of ascending colon to splenic end of descending colon). Duration of operation: 3 hours 35 minutes. Continuous spinal anesthesia. Received 2,400 cc. blood, 500 cc. plasma and 3,300 cc. saline intravenously. At termination of operation there was no gross evidence of neoplasm remaining in the abdomen. Satisfactory convalescence, received palliation for over 2 months, the patient succumbed from rapidly developing generalized sarcomatosis that proved resistant to irradiation. Period of deterioration lasted 2 weeks.

quadrant, 30 cm. of ileum with corresponding mesentery extending up to origin of superior mesenteric artery and including metastatic nodes palpable up to this artery for carcinoma of sigmoid invading loop of ileum to production of ileocolic fistula, also invading dome of urinary bladder, intra-abdominal portion of left spermatic cord and abdominal wall in left lower quadrant. Side-to-side entero-enterostomy, closure of remaining urinary bladder, double-barrel colostomy. Latter subsequently closed.  
Result: Survived 14 months; died of recurrences. Returned to heavy physical work (truck driver) for six months.

Case 4.—S. P. (No. 264586). Male, age 68.

Resection *en masse* of gallbladder, surrounding liver parenchyma, all extrahepatic bile ducts except for small terminal stump of common duct, and portion of head of pancreas, for carcinoma primary in extrahepatic bile ducts. T-tube inserted between right hepatic duct sinus in liver and stump of common duct at duodenum. The left hepatic duct stump was cannulated with urethral catheter; the latter came away in two months and sinus closed. No discharge of bile about T-tube.

Result: Icterus cleared, relieved of pain. Survived one year, returned to full-time normal occupation (accountant) for six months. Died of recurrences.

Space does not permit of the detailed description of each of the 100 patients in the series considered in this report. The results are classified into four groups as follows:

GROUP IV.—Thirty-four patients: Operative mortality. In this study patients dying within four weeks of operation are classified as operative deaths regardless of other possible causes. Some apparently died of carcinoma but this did not alter their classification in view of the time of survival after operation. The causes of death are summarized in Table I.

GROUP III: Fourteen patients. During the period of survival palliation was minimal or did not obtain. At this writing three are alive, averaging four months since operation. Of the 11 patients who have died, all of carcinoma, the average postoperative survival was two and seven-tenths months. Two lived five, and five and five-tenths months, respectively; one, four months; two, three months, respectively, and six, one to two months.

GROUP II-a: Twenty-three patients. This group includes patients who survived over one month to 14 months, received varying degrees of palliation

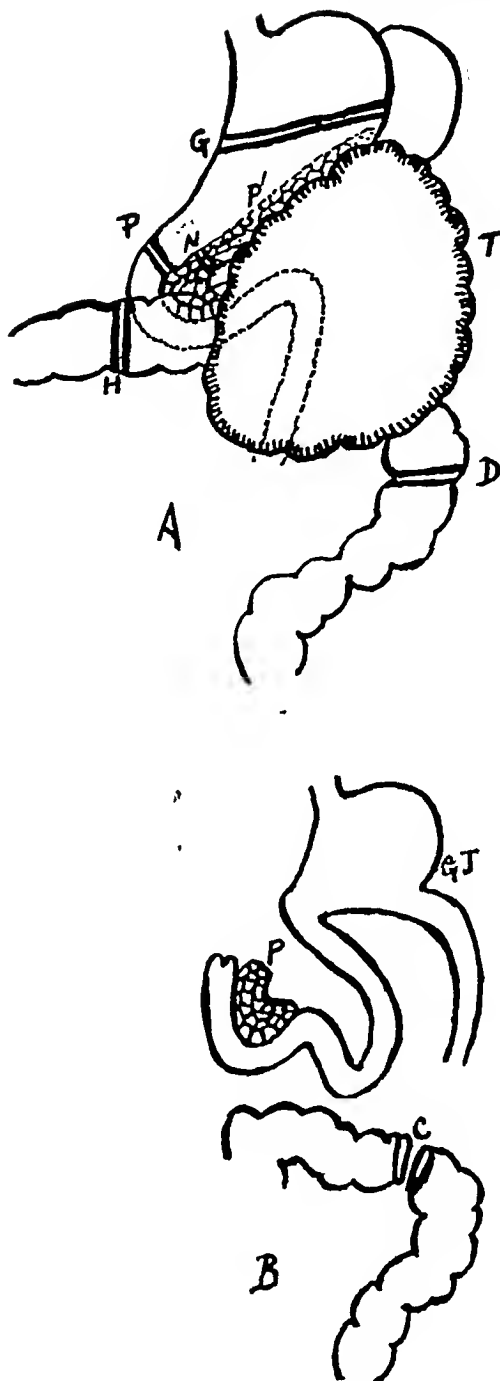


FIG. 2A.—Case 332950: Diagram of operation showing levels of transection: (G) division of stomach; (P) pylorus; (N) neck of pancreas; (P') body of pancreas excised with specimen; (N') neck of pancreas transected; (H) transverse colon transected near hepatic flexure; (D) descending colon near junction with splenic flexure.

(B) Situation at close of operation; (GJ) gastrojejunostomy; (P) transected neck of pancreas; (C) colostomy, hepatic flexure to upper portion of splenic segment of colon.

which, however, it is felt was sufficient to have justified operation and who since have died of carcinoma. The average period of survival was five and eight-tenths months. Five patients survived 10, 11, 12, 14 and 14 months, respectively. Three patients survived six to seven months.

TABLE I

CAUSE OF DEATH IN 34 PATIENTS SUBJECTED TO RADICAL RESECTION OF ADVANCED ABDOMINAL CANCER	
Peritonitis—No gross evidence of perforations.....	6
Peritonitis—Ischemic perforations or leakage of anastomosis (1 case).....	6
Pulmonary complications (pneumonia).....	6
Accidental resection of segment of hepatic artery.....	2
Accidental ligation of superior mesenteric vein.....	1
Thromboses, intrahepatic radicals of portal vein.....	2
Uremia.....	1
"Exhaustion." Patients markedly debilitated by carcinomatosis, no specific cause of death revealed at necropsy.....	2
Acute gastric dilatation.....	1
Multiple thrombi splanchnic vessels and ischemic necrosis, gastric stump.....	1
Acute adrenal insufficiency.....	1
Necropsy not obtained.....	5
Total.....	34

GROUP II-b: Twelve patients. This group comprises the patients who have survived operation at least two months, have received sufficient palliation to have justified operation and who are living at this writing. Four who have survived operation an average of four and two-tenths months have clinical evidence of advancing disease but are considered to be in better condition than before operation. Four are living, well, and returned to usual full-time occupation, 12, 11, eight and eight months after operation, respectively. Four have been operated upon two to three months previous to this report, and are well.

GROUP I-a: Twelve patients. Prolonged palliation, survival at least 18 months, returned to usual occupation full-time. No evidence of carcinoma.

GROUP I-b: Five patients, prolonged palliation but eventually died of recurrent carcinoma.

The question might be raised that patients in Groups I-a and I-b include lesions which are not "advanced" and, thus, received more conservative operations than those in the other groups. That this was not the case is shown in Table II which summarizes the extent of the neoplasms and the operative procedures.

Ten patients are living and well an average of four years after operation (Group I-a). Five patients have died of recurrent and metastatic carcinoma, having survived operation for an average of two and one-half years (Group I-b).

Included in Group I-a are two patients who were subjected to multiple stage radical resections of the pelvic colon in the face of clinical evidence of recurrent and metastatic carcinoma of the uterus following irradiation therapy. In both instances the primary growths (biopsied) were of such size as to leave the impression that their eradication by irradiation would probably not be successful. When readmitted they presented obstruction of the colon and

TABLE II

SUMMARY OF OPERATIVE PROCEDURES AND RESULTS IN  
PATIENTS IN GROUPS 1a AND 1b DESCRIBED IN TEXT

GROUP 1-a.	Findings and Procedure	Result
Patient and Hosp. No.		
1. E. C. (134969)	Carcinoma first loop of jejunum extending upward in mesentery, into body of pancreas and posterior to this into retroperitoneal tissues. Resection of 10 cm. of upper loop of jejunum with involved mesentery, distal third of body of pancreas and upper retroperitoneal extensions. End-to-end jejejunostomy and gastrojejunostomy distal to this.	Well 10 yrs.
2. R. H. (186022)	Large ulcerating carcinoma second portion of duodenum invading adjacent pancreas. Resection of inner curvature of second portion of duodenum and subjacent pancreatic tissue.	Well 7 years, 4 months
3. N. A. (261816)	Carcinoma of lower third of stomach directly invading left lobe of liver, one detached metastasis in left lobe. Resection of lower three-fifths of stomach and left lobe of liver <i>en masse</i> .	Well 4 years, 2 months
4. R. Z. (263077)	Carcinoma hepatic flexure with invasion of capsule of right lobe of liver and invasion of loop of ileum 20 cm. proximal to cecum. Right hemicolectomy with resection of lower 30 cm of ileum, all corresponding mesenteries and involved portion of right lobe of liver 10 x 6 x 4 cm. Ileotransverse colectomy.	Well 3 years, 8 months
5. H. S. (27336)	Large fungating carcinoma of fundus of stomach with extensive lymph node metastases in gastrohepatic ligament and throughout most of omentum. Total gastrectomy and omentectomy, splenectomy. Transection of esophagus about 1 cm. beyond gross limits of tumor.	Well 3 years, 6 months
6. J. C. (287119)	Large carcinoma of transverse colon invading stomach above and fungating through abdominal wall in periumbilical region. Resection <i>en masse</i> of transverse and ascending colon, lower 15 cm. of ileum, segment of abdominal wall 8 x 6 cm., including skin and umbilicus, lower half of stomach. Ileosplenic flexure colostomy. Pólya gastrojejunostomy; repair defect in abdominal wall (Fig. 4).	Well 3 years, 6 months
7. G. J. (142751)	Resection of lower half of head of pancreas, lower half of duodenum, regional lymph node metastases, double fist-size spindle cell sarcoma of third portion of duodenum. During operation superior mesenteric vessels were dissected free from tumor. Duodenojejunostomy.	Well 3 years
8. L. L. (284407)	Massive carcinoma of left adrenal invading diaphragm above, musculature of posterior abdominal wall left side, surrounding upper pole left kidney and apparently invading body and tail of pancreas. Resection of tumor, left kidney, body and tail of pancreas, spleen, portion of left diaphragm and muscle and fascia of left posterior abdominal wall.	Well 3 years
9. N. G. (2648)	One-stage pancreatoduodenectomy for large carcinoma of ampulla of Vater with regional lymph node metastases resected including a large node high in the porta hepatis.	Well 2½ years
10. L. R. (332950)	Large carcinoma left transverse colon with invasion of lower stomach and body of pancreas. Resection <i>en masse</i> of lower half of stomach, spleen, body and tail of pancreas, left three-fourths of transverse colon, descending colon and entire omentum. Double-barrel colostomy—hepatic flexure to sigmoid in left abdominal wall; subsequent closure of the latter (Fig. 2).	Well 1 year, 7 months
GROUP 1-b		
1. J. L. (233821)	Massive islet cell carcinoma of body of pancreas, 15 cm. in diameter, invading stomach and segment of upper jejunum. Resection of body of pancreas, tumor, spleen, portions of gastric and jejunal wall invaded by tumor.	Lived 3 years, 11 mos. Died of complications of celiotomy performed for resection of metastases
2. R. W. (287625)	One-stage pancreatoduodenectomy for large carcinoma termination of common bile duct.	Lived 2 years, 2 mos. Died—recurrences
3. C. B. (235477)	Multiple resections of right colon and portions of abdominal wall for recurring carcinoma. Well and active during intervals between operations.	Lived 2 years, 6 mos. Died coronary occlusion 3 weeks after 3rd celiotomy. Had extensive recurrences
4. C. G. (239588)	Resection of transverse and descending colon and segments of ileum and jejunum for obstructing metastases from gastric carcinoma resected two years previously.	Lived 2 years, 2 mos. Normally active for almost 2 years following operation
5. O. A. (132357)	Subtotal gastrectomy for carcinoma of stomach with extensive lymph node and omental metastases. Carcinoma had perforated 2 months previously and was repaired in another institution.	Lived 2 years. Normally active during most of this period. Died of metastases



# ADVANCED INTRA-ABDOMINAL CANCER

extensive pelvic induration. It was the impression that the obstruction was due to recurrent pelvic neoplasm. Conservative management would have indicated loop-colostomy only. However, since biopsies of the adnexal regions at the time loop-colostomy was done for immediate relief of the obstruction failed to reveal carcinoma, subsequent procedures were carried out to excise the obstructed segments of pelvic colon and in each instance it was discovered that the lesion was irradiation necrosis, ulceration and stenosis of the colon. At present both these patients are living and well four years after final reestablishment of continuity of the bowel.

FIG. 2 (Continued)



FIG. 2C.—Case 332950: Photograph of surgical specimen showing: (T) large carcinoma of transverse colon; (O) entire omentum; (S) spleen; (St) lower half of stomach; (H) transected colon at hepatic flexure; (D) transected colon at junction of descending portion with sigmoid. Body and tail of pancreas and left adrenal gland also resected are on reverse side of specimen and hence not seen. Duration of operation: 3 hours and 20 minutes. He received 1,100 cc. of blood and 2,300 cc. of normal saline solution. The patient is well and at work full-time in usual occupation, 18 months after operation. He requested and received repair of ventral hernia (incisional) 12 months after above operation and at this time exploration of the abdomen revealed no evidence of recurrences or metastases.

A recapitulation of the results discussed above is given in Table III.

**Discussion.**—The contraindications for radical extension of operative attack upon advanced abdominal cancer are: (a) widespread peritoneal metastases; (b) extensive hepatic metastases; and (c) inability to encompass the growths by the incisions for resection. However, there may be exceptions to these "rules." For example, in one instance of carcinoma of the body of the pancreas producing very severe pain and found to have numerous intrahepatic

TABLE III

## RECAPITULATION OF RESULTS

Total number of patients.....	100
Operative mortality.....	34%
Survived operation up to 5.5 months—little or no palliation.....	14%
Survived operation up to 14 months—received palliation.....	23%
Living up to 12 months after operation—receiving palliation.....	12%
Survived operation average of 2.5 years—returned to usual activities but since died of carcinoma....	5%
Surviving operation, average of 4 years, returned to normal full-time activities.....	12%*

\* Two patients (2%) following radical resections proved not to have recurrent carcinoma, although latter was initially present, as confirmed by biopsy, as previously described.



FIG. 3.—Case 274690: Photograph of multiple metastases excised from various portions of the abdomen 4 years after previous operation at which time primary cystadenocarcinoma of right ovary was resected with drainage of pseudomucinous peritonitis. (L L') metastases removed from anterior surfaces of right and left lobes of liver, respectively; (S) metastases removed from serosal surfaces of jejunum and ileum; (U) metastases removed from mesentery of jejunum; (T) metastasis removed from mesentery of ileum; (A) metastasis resected from right lower quadrant of abdominal wall with portion of rectus muscle; (P) mass of recurrent carcinoma excised from cul-de-sac of Douglas. The patient continues in full-time occupation, has maintained 30-pound weight gain and is otherwise well 9 months after operation.

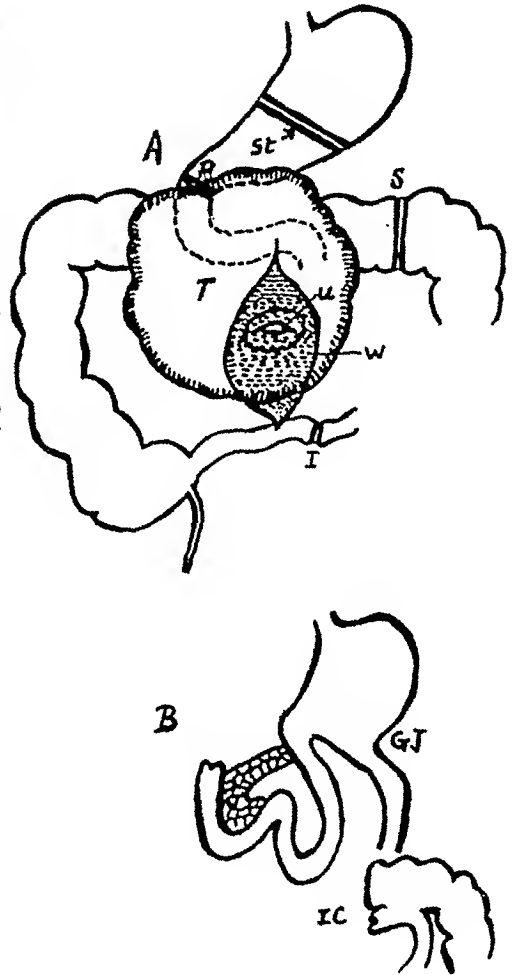


FIG. 4

FIG. 4A.—Case 287119: Diagram showing levels of transection; (St) through midportion of stomach; (P) pylorus; (S) splenic flexure of stomach; (I) lower ileum; (U) umbilicus and (W) surrounding portion of abdominal wall invaded by (T) large carcinoma primary in central portion of transverse colon. The umbilicus and abdominal wall were resected *en masse* with the neoplasm, etc.

(B) Situation at the termination of the operation; (GJ) gastrojejunostomy; (IC) ileotransverse colostomy (splenic flexure).

metastases, (the patient was a physician), resection of the body of the pancreas and spleen was, nevertheless, carried out. During the five and one-half-weeks period of survival pain was almost completely relieved. This may well have been due to interruption of sympathetic nerves. In a young male combined abdomino-perineal resection was performed for carcinoma of the colon in the face of diffuse hepatic (but no peritoneal) metastases, since rectal tenesmus was very severe. Relief from this was obtained and the patient survived seven

FIG. 4 (Continued)



C

FIG. 4C.—Case 287119: Photograph of surgical specimen consisting of (TT') large carcinoma arising in and involving right transverse and hepatic flexures of colon that extended upward onto stomach, the lower half of which was resected, and anteriorly along falciform into anterior abdominal wall. (U) Umbilicus and surrounding shaded area indicates extent of abdominal wall (skin, fascia and musculature) also removed to encompass tumor. (I) transected ileum about 8 cm. above cecum; (a) ascending colon; (sp) splenic flexure; (O) omentum. Operation terminated by ileosplenic flexure colostomy. Duration of operation: 3 hours and 15 minutes. Received 1,200 cc. blood and 1,500 cc. normal saline solution. Patient living and well 3 years 6 months after operation, with no evidence of recurrences.

months, gaining ten pounds in weight and was ambulatory for most of this period. A young adult female (Case 274690) patient, weighing 90 pounds, was subjected to exploratory celiotomy because of marked swelling of the abdomen. Extensive peritoneal implants from cystadenocarcinoma of the right ovary were found. The ascites was drained and ovaries removed together with much of the diffuse metastases. Roentgenotherapy was subsequently administered and for four years she returned to normal activity. On the occasion of a follow-up visit a mass was palpable in the cul-de-sac of Douglas and deep induration was present in the right lower quadrant of the abdominal wall. There were no complaints, the 30-pound weight gain was maintained. Nevertheless, celiotomy

was performed and numerous metastases excised from the surfaces of the small bowel, anterior surfaces of the right and left lobes of the liver, from within the mesentery of jejunum and ileum, a mass was resected from the cul-de-sac of Douglas, and muscularis invaded by tumor was resected from the abdominal wall in the right lower quadrant (Fig. 3). Recovery was prompt and in a few weeks she returned to her usual occupation as an office worker. She remains well nine months after the above operation.

It would be difficult to attempt prognosis in individual patients as to whom might receive effective palliation and who would not receive benefits from radical excision. The decision to proceed with operation is governed by several individual factors but obviously when all macroscopic evidence of neoplasm can be resected, there are definite opportunities for effective palliation. On the basis of the experiences summarized above, 50 per cent of patients representing a group hitherto regarded as beyond hope of appreciable benefits from radical surgical therapy were afforded some measure of relief which it is believed could hardly have been received by conservative procedures. The surgical mortality, *i.e.*, 34 per cent, was not excessive given the situations encountered and especially when exploratory celiotomy alone in advanced gastric cancer is reportedly 20 to 25 per cent and for total gastrectomy in general hands is probably in excess of 70 per cent. Increased experience will permit of better judgment in the performances of radical resections for advanced abdominal cancer as well as refinements in technic.

#### CONCLUSIONS

Progress in supportive treatment of the surgical patient permits of the extension of radical surgical attack upon advanced abdominal cancer. Experiences in a series of 100 patients revealed that effective, albeit in some instances brief, palliation was afforded in 35 per cent with appreciable and prolonged palliation achieved in an additional 15 per cent of the series. Given adequate conditions, a more radical attitude in regard to the surgical treatment of advanced abdominal cancer would appear justifiable.

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# SURGICAL RELIEF OF TREMOR AT REST

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THAT TREMOR AT REST arises from the activity of the precentral cortex (regardless of the location of the lesions responsible for the disease) has gradually become increasingly clear. In 1817, Parkinson<sup>11</sup> noted in his Case 6 that the tremor at rest, which had been generalized, was abolished from the right side during the two weeks that side was paralyzed as the result of an apoplectic seizure. Patrick and Levy,<sup>12</sup> in 1922, and Balser,<sup>1</sup> in 1942, made similar observations. However, in such cases the damage from the cerebrovascular disease has been too extensive to permit one to determine accurately the cortical area and the pathway primarily concerned with the production of tremor (Balser<sup>1</sup>). In addition, in 1937, I had abolished both tremor at rest and intention tremor from the right upper extremity by extirpating the "arm" area from areas 4 and 6 of the left precentral gyrus and the neighboring frontal convolutions.<sup>7</sup> This observation definitely established the fact that these tremors, though probably released by destructive lesions in the subcortical nuclei, are produced by nervous impulses arising from the precentral motor cortex (areas 4 and 6). However, it left doubt as to whether these impulses responsible for the involuntary movements of tremor are mediated *via* the pyramidal fibers from area 4 or the extrapyramidal fibers from areas 4 and 6. Putnam<sup>13</sup> helped to clarify this question. In 1938, he demonstrated that tremor at rest is abolished by section of the lateral pyramidal tract in the cervical spinal cord. He subsequently confirmed this observation in several additional cases.

Fibers in the pyramidal tract arise from various places other than the precentral motor cortex (Tower<sup>14</sup>). Whether these nonprecentral origins are confined to the cerebral cortex (particularly the parietal region), as Mettler<sup>10</sup> believes, is not as yet a matter of general agreement. However, the clinical observations cited above demonstrate that only those pyramidal fibers arising from the precentral region are concerned with the production of tremor and in the precentral region pyramidal fibers arise only from area 4 (Tower<sup>14</sup>), which in man is confined to the precentral gyrus (von Bonin<sup>2</sup>). Architecturally, area 4 in man is divisible into three parts: area 4 $\gamma$ , area 4 $\alpha$  and area 4 $\delta$  (von Bonin<sup>2</sup>), all of which probably contribute to the pyramidal tract. However, the large pyramidal fibers (over 9 $\mu$ ), which form only two to three per cent of all of the pyramidal fibers, probably arise from the Betz cells which are to be found only in area 4 $\gamma$ . Area 4 $\gamma$ , in turn, forms the posterior part of the precentral gyrus (Fig. 1). The possibility existed that only the Betz cells and these large fibers are concerned with the production of tremor. If this

were true then cortical extirpations could be restricted to the posterior part of the precentral gyrus (area 4 $\gamma$ ), and areas 4a, 4s and 6 could be preserved. It seemed likely that such a limited extirpation would produce less paralysis and leave a more useful extremity than was obtained following the larger extirpation of areas 4 and 6. The following case presented an excellent opportunity to test this possibility.

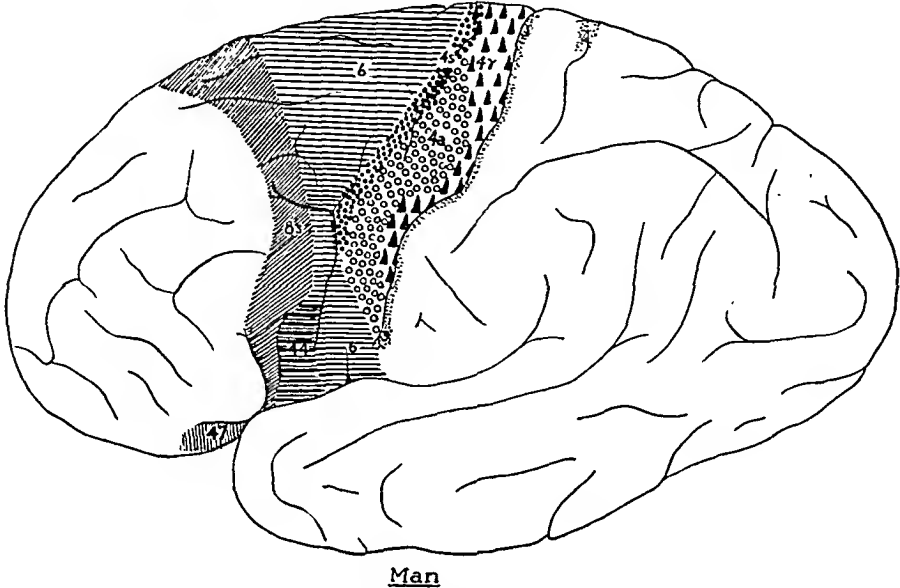


FIG. 1.—The human precentral motor cortex (areas 4 $\gamma$ , 4a, 4s, 6 and 44) and some adjacent areas.

**Case Report.**—P. di F. was referred by Dr. Daniel H. Levinthal of Chicago, Illinois. He was born in Chicago of Italian parents. He was 23 years of age and single. He had been under observation both in the hospital and in the dispensary at the Illinois Neuropsychiatric Institute for some time. On July 29, 1943, he was admitted to the hospital for operation. This young man came complaining of marked weakness of the right arm and leg and of a tremor, involving these extremities, for 15 years, since he was eight years old. His father informed us that the patient had been a normal healthy child until about the age of 5.5 years, when he had a rather severe attack of "influenza," or "pneumonia." He was ill for approximately three or four weeks. The exact nature of this illness we were unable to learn. However, he seemed to recover from it completely and to remain well until two years later, when he was 7.5 years old. At that time his school teacher noticed that he was beginning to limp and that the right extremities were weak. A short time later a tremor appeared in these extremities. This was, and always has been, worse on excitement and has disappeared during sleep. It has always been most marked with the extremities at rest, and often disappeared during the execution of voluntary movements. The tremor and weakness gradually increased in severity, and, whereas, originally the tremor was not constantly present, it was present during all of his waking hours for the five years prior to admission. For three years, that is, since the age of 20, his speech had been much more indistinct than formerly.

Nothing else in the patient's past medical history or in the family history seemed relevant to his present condition.

**Physical Examination.**—The temperature, pulse and respiratory rate were normal, the blood pressure was 120/76. He was a fairly well-developed and well-nourished white man, with an expressionless face and a marked tremor of the extremities on the right side of his body. He spoke haltingly, and it was at times with difficulty that he was

understood. He was said to be right-handed. He walked with a marked limp, favoring the right lower extremity. There was a scoliosis and a rotation of the trunk, such that the right hip was thrown posteriorly and the right shoulder thrown anteriorly, and he leaned toward the right side. The general physical examination was otherwise negative. The cranial nerves were intact except that the left pupil was slightly smaller than the right and slightly irregular. Both reacted normally to light and on accommodation. There were no oculogyric crises. There was a slight transient nystagmus, particularly on looking to the right. At times fasciculation of the masseter muscles on the left side was seen. There was a definite right lower facial weakness, both on volitional and emotional movement. Auditory acuity was reduced slightly bilaterally. The right shoulder was held elevated and thrust forward. There was, however, no weakness of the sternocleidomastoid muscle or of the trapezius. The tongue protruded in the midline. Because of the violent tremor involving the right extremities, it was difficult to appraise the tendon reflexes. It was finally concluded, however, that they were definitely increased throughout the entire right side of the body, although they were normally active on the left side. The abdominal reflexes were active bilaterally, as were the cremasterics. Hoffmann's sign was not present. The jaw jerk seemed to be increased. There was a suggestive Babinski sign on the right side only. No clonus was elicited. There was weakness at the wrist on the right side but the grasp was quite strong. There was also weakness of the movements of the thumb and the fingers on the right side. Otherwise strength in the right upper extremity was good, although useful activity was practically prevented by the rigidity and the tremor. There was some weakness of the right lower extremity. He walked with a typical spastic hemiplegic gait, tending to drag the foot and circumduct it. The lower extremity was also internally rotated, so as to throw the greater trochanter forward. Actual weakness of the lower extremity, when individual groups of muscles were tested, was, however, slight. There was definite reduction in the volume of the muscles throughout the entire right side. This was perhaps most noticeable in the interossei of the hand. There was definite cogwheel rigidity throughout the right side. There was a pes equinus deformity of the right foot, with contracture of the gastrocnemius and soleus muscles on that side. There was definite diminution in size of the gluteus muscles on the right side. Finger-to-nose and heel-to-knee tests were reasonably well done except that on the right side the tremor interfered somewhat with these tests. Sensation in all forms was intact everywhere.

There was a marked tremor involving both the right upper and lower extremities. The oscillations were at approximately three to four per second. They involved the entire extremity but were most pronounced in the distal half. There was a tendency toward pill-rolling in the right hand, and a marked flexion tremor at the wrist. Both the tremor and the rigidity were more marked in the right upper than in the lower extremity. The tremor was predominantly a tremor at rest, although it was not completely absent during voluntary movement. He had a rather expressionless face; his speech was slow and drawling and hesitant. At times it seemed as though there were a slight motor aphasia in that he did not finally say the word that he started with. However, on detailed tests for aphasia, there were no definitely positive findings. He was slow in his responses, his intelligence was not above average, and he occasionally stuttered. A diagnosis of unilateral right parkinsonism resulting from a chronic encephalitis was made and was concurred in by all who saw and examined him.

*Laboratory Data.*—Urinalysis was negative, the blood count was normal, the Wassermann and Kahn tests on the blood were negative. A lumbar puncture was made, the cerebrospinal fluid contained 9 mg. of protein per 100 cc. of fluid, the Wassermann test was negative, the colloidal gold curve was flat, and the fluid contained two cells per cubic millimeter. An electro-encephalogram was made, which showed some spike-like waves of slow frequency to either side of the midline in the frontal region.

The patient was given hyoscine hydrobromide and tincture of stramonium without benefit.

*Operation.*—On August 3, 1943, under ether anesthesia, an osteoplastic flap was reflected in the left parietal region, exposing the central sector of the cortex of the left cerebral hemisphere up to the midline, and with the fissure of Rolando in the middle of the operative field. The exposed cortex did not appear abnormal. Photographs were taken of it (Fig. 2) and a sketch of the cortex was made by Dr. Percival Bailey (Fig. 3). All of the exposed cortex was then carefully stimulated with a 60-cycle sine wave current, using a bipolar electrode. Motor responses were obtained only from the posterior part of the precentral gyrus (Fig. 3). As noted in a previous publication



FIG. 2.—Photograph of the left central region after extirpation of the posterior half of the precentral gyrus and, thus, of area 47 in the "arm" and "leg" fields.

with Dr. Garol,<sup>9</sup> stimulation of an area just anterior to the precentral gyrus and just ventral to the posterior end of the first frontal sulcus or superior frontal sulcus, caused a suppression of peripheral motor response. This area presumably corresponds to area 4s in the subhuman primates. As this response was previously described in detail,<sup>9</sup> it need not be further alluded to here. The threshold for motor responses from the posterior part of the precentral gyrus was 1.6 volts. Movements were elicited in the head region and in both the right upper and lower extremities, as indicated on the accompanying diagram (Fig. 3). When the current was increased to 2.5 volts, a typical motor after-discharge was produced. The posterior one-half of the precentral gyrus in those regions from which movement of the right upper and lower extremities had been produced, was then removed subpially down to the bottom of the central sulcus (Fig. 2). The great rolandic vein and the communicating vein, which crossed the region of the extirpation were left intact. The extirpation extended down the medial surface of the hemisphere to the first sulcus. The dura mater was then closed tightly, the osteoplastic flap replaced and held in place with silk sutures and the scalp wound closed as usual.

*Postoperative Course.*—The operation was completed at 4:30 P.M. At 6:00 P.M., the patient was awake and able to coöperate in a limited examination. There was a com-



plete paralysis of the right upper extremity, and although there was marked weakness of the right lower extremity, he was able to flex the hip. There was definitely increased resistance to passive stretching of the flexors of the right upper extremity. All tendon reflexes on the right side were hyperactive; clonus could be elicited at the right ankle; Hoffmann's sign could be elicited in the right hand; Babinski's sign was present on the right side; the right abdominal reflexes were absent; but the cremasteric reflexes were all present; there was a right facial weakness; all sensation was intact, including

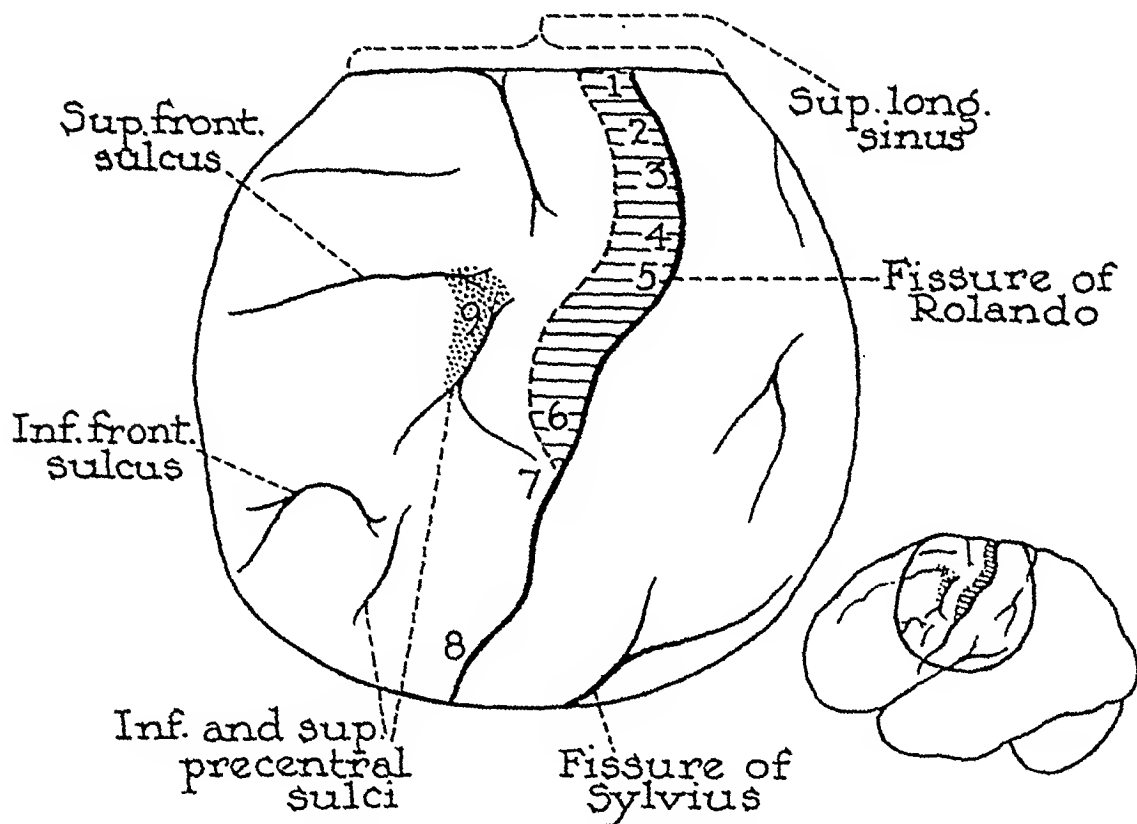


FIG. 3.—Artist's elaboration of a sketch of the cerebral cortex exposed at operation. The insert indicates the general relation of the exposed cerebral cortex. The numbers designate areas of various responses to electrical stimulation. The area for flexion of the right hip is indicated by 1; for contraction of the right quadriceps femoris muscle, by 2; for contraction of the right pectoralis major muscle, by 3; for flexion of the fingers of the right hand, by 4; for flexion of the right elbow and wrist, by 5; for movement of the neck and right shoulder, by 6; for movement of the right corner of the mouth and contraction of the right platysma myoides muscle, by 7; for movement of the lower lip on the right side, by 8, and for the suppressor area—areas 4s, by 9. The area which was extirpated has been indicated by cross-hatching.

light touch, pain sensibility as determined by pinprick, the perception of differences in temperature, vibratory sense, position sense and the recognition of the shape of objects (stereognostic sense).

On the first postoperative day (8-4-43), at 9:00 A.M., his speech was the same as before operation. He was able to abduct the right arm at the shoulder for about  $10^{\circ}$  to  $15^{\circ}$ . This movement was performed only after a considerable latent period and with considerable difficulty. He was also able to flex the right elbow after a considerable latent period, and also weakly. He could flex the right hip quite well, probably as well as he could before operation. He was able to extend the right knee about 50 per cent as well as prior to operation. However, he was unable to flex the knee or to move the ankle, the toes, the wrist or the fingers. There was a moderately increased resistance to passive flexion of the elbow, but only after the elbow had been flexed to  $90^{\circ}$  and a similar resistance to passive extension of the right elbow, after it had been extended to approximately  $135^{\circ}$ . There was a definite reduction in the sense of position in the right fingers to approximately 50 per cent of absolute accuracy. However, he

was conscious of each passive movement of the finger, and he was able to identify each finger touch accurately. With his eyes closed he erred by as much as six to ten inches in trying to find his right hand with the left. There was no reduction in pain sensibility, as tested with pinprick on either side. All of the tremor which had been present preoperatively was completely abolished and remained so thereafter. There was marked perspiration, involving the entire right arm and right leg, while the left extremities were perfectly dry. Babinski's sign was present.

On the second postoperative day, the right abdominal reflexes had returned, but they were not as active as those on the left side. The cremasteric reflexes, however, were equally active on the two sides. The marked perspiration continued on the right side of the body and involved the head, right arm and upper part of the trunk more than it did the lower part of the trunk and the right lower extremity. Position sense was grossly defective in the right fingers but quite accurate in the toes.

Movement in the right upper extremity was much less than it had been on the first postoperative day and was reduced to limited feeble twitch-like movements at the right shoulder. Movement in the right lower extremities were, likewise, reduced as compared with the first postoperative day. Resistance to passive movement in both the flexors and extensors, in both the upper and lower extremities, on the right side, was more marked. On August 7th, the fourth postoperative day, the excessive perspiration on the right side of the body still continued. The tremor was still completely abolished. He was able to identify individual fingers on the right side, but his sense of position in the right fingers and his ability to find the right hand with his left hand when his eyes were closed was grossly defective. Vibratory sense was only very slightly diminished on the right side. Sense of position was excellent in the toes and at the wrists. The reflexes were the same as they had been on the first and second postoperative days. Perception of pinprick was normal and the perception of alterations in temperature was acute over his entire body. The ability to recognize objects with his right hand, although not abolished, was definitely impaired. He could recognize numbers written on the palms of the hands, but on the right side it was necessary for these numbers to be three and one-half centimeters high, whereas numbers one and one-half centimeters high were properly recognized on the left side. He was able to detect gross differences in the weight of objects placed in his right hand. Movements at the right shoulder and elbow continued to increase in strength, but there was still no movement at the wrist or of the fingers. Likewise, movements of the hip and knee on the right side continued to increase, whereas there was still no movement at the ankle or of the toes. This condition continued gradually to improve. By the twentieth postoperative day, August 23, 1943, the tremor continued to be entirely abolished; he was able to walk almost as well as before the operation and he had become able to flex his fingers, but could not extend them. In the lower extremities individual movements at the hip and knee had continued to gain in strength, but he was unable to move the ankle or the toes. There was a slight increase in resistance to passive movement on the right side. All tendon reflexes on that side were markedly increased and Babinski's sign was still present. Clonus could be elicited at both the knee and ankle. Hoffmann's sign was present on the right side. Both the abdominal and cremasteric reflexes were active on both sides of the body. There was no disturbance of sensation including light touch, pinprick, alterations in temperature, vibration and position sense. On September 4, 1943, one month after the operation, the patient was discharged from the hospital. The tremor was still completely abolished, and has remained so up to the present time.

By September 30, 1943, almost two months after the operation, he was walking better than prior to the operation. He was able to shake hands using his right hand. Strength in the right extremities had improved greatly. He now could not only flex the right hand and fingers, but could extend the fingers and thumb as well. In October he obtained a job in a laundry handling bundles, but he found that he had to discontinue

it because of difficulty in maintaining his balance when attempting to carry bundles and walk up stairs. By January 4, 1944, five months after the operation, he was able to tie his shoes and his necktie, using both the right and the left hand, to grasp. His right hand had increased in strength.

On May 3, 1944, nine months after the operation, he was able to walk with his body upright, although with a definite hemiparetic gait. He did not swing his right arm as he walked. There was a definite moderately spastic hemiparesis on the right side, much the same as prior to the operation. All tendon reflexes were increased on that side. Hoffmann's sign was present on the right side, as was Babinski's sign. Ankle and patellar clonus were still readily elicited. The musculature on the right side was definitely atrophic as compared with the left, just as it had been prior to the operation. There was no disturbance of sensation anywhere. The violent tremor at rest which had been present prior to operation had never returned. His speech was still slow and rather monotonous as it had always been. When last seen, on December 13, 1944, over 16 months after the operation, the tremor was still absent. Useful voluntary movements of the right upper extremity were very limited. He walked better than before the operation, although in a similar fashion.

**DISCUSSION.**—These observations present several points of interest, particularly as concerns the effect of the extirpation of area 4 $\gamma$  upon tremor at rest, upon paralysis and spasticity, upon sensation and upon perspiration.

*Tremor:* Extirpation of the "arm" and "leg" portions of area 4 $\gamma$  (the posterior part of the precentral gyrus) abolishes tremor at rest in the contralateral upper and lower extremities. The tremor was abolished immediately after the operation and has not returned during the subsequent 16 months that the patient has been observed. This would indicate that tremor at rest arises from the activity of the Betz cells and is produced by nervous impulses mediated by the large (9 to 22 $\mu$  fibers), which form two to three per cent of the pyramidal tract.

These conclusions relative to the mechanism responsible for the actual production of tremor at rest have no bearing upon the question of what structures must be destroyed for tremor at rest to appear. It is very likely, as I<sup>5</sup> have previously noted, that destruction of the substantia nigra or of the globus pallidus, or of both, is the most common lesion which releases the pyramidal system to this form of abnormal hyperactivity.

*Paralysis:* This young man was not the ideal patient upon which to determine the degree of paralysis resulting from the removal of area 4 $\gamma$ . He had some paralysis before the operation. Nevertheless, following the operation he had much more paralysis particularly in the upper extremity and particularly in the distal parts (hand, fingers and foot) than before the operation. In the hand this has prevented much utilization of the upper extremity, although the disability has been somewhat less than in those cases where areas 4 and 6 were removed (Bucy<sup>4</sup>). In the lower extremity the disability does not appear to be much, if any greater than before the operation.

*Spasticity:* Although the resistance to passive manipulation of the right extremities is not great it is definitely more than before the operation. Furthermore, the tendon reflexes are much more active than before the operation,

clonus is readily elicited and Hoffmann's sign has appeared in a forthright manner. This all strongly indicates that in man inhibition of the postural and myotatic reflexes is not limited in the precentral motor cortex to area 4s but is also represented to some degree in area 4y. Admittedly, this case does not definitely establish that as a fact for there is no evidence as to possible operative or postoperative damage to area 4s.

*Sensation:* This case, along with previous similar observations (Bucy<sup>6</sup>), leaves little doubt that the precentral gyrus is not concerned with the conscious perception of sensory stimuli. Earlier, many individuals had observed that removal of the precentral gyrus results in impairment of some forms of sensibility on the opposite half of the body. In the vast majority of instances this sensory impairment is temporary. This case clearly establishes the fact that the sensory loss does not appear immediately after the destruction of the precentral tissue as would be the case if it resulted directly from that cortical extirpation. Rather the sensory deficiency appears gradually several hours after the extirpation as would be expected if it were due to the impairment of the circulation of the neighboring structures, notably the postcentral gyrus, from edema and venous thromboses secondary to the operation.

*Perspiration:* The observation that the right half of the body perspired very profusely for several days after the extirpation is peculiar, in my experience, to this case. This would seem to indicate that area 4y is concerned with the control of perspiration, probably through the sympathetic system. In this instance the excessive perspiration could be interpreted as resulting from the removal of cortical inhibition from the sympathetic nervous system, releasing it to temporary hyperactivity. Similarly, several years ago, I<sup>3</sup> reported another case in which a presumed capsular hemiplegia was associated with unilateral vascular spasm, abolition of the pulse, inability to obtain the blood pressure, cyanosis and coldness of the paralyzed extremities. In this instance, too, a release of cortical inhibition over the sympathetic nervous system was postulated.

How the present observation correlates with that previously reported with Pribram,<sup>8</sup> in which a tumor beneath the lower end of the right precentral gyrus was associated with epileptiform convulsions of the left half of the face and associated attacks of localized sweating of the left side of the face and left upper extremity, is not as yet entirely clear. Both observations indicate that the precentral region exercises some control over the mechanism of sweating and that control is a localized one, as evidenced by the unilateral sweating in the present case and the limitation of the sweating to a small part of one side of the body in the case recorded with Pribram<sup>8</sup>

*Aphasia:* In previous cases where a more extensive extirpation of the left precentral region was made for the relief of involuntary movements a temporary motor aphasia developed.<sup>4</sup> In this case, with a much more limited extirpation, there was at no time any such disturbance of speech.

*Suppression:* Garol and I<sup>9</sup> have already reported the demonstration for

the first time of the suppressor activity of area 4s in the human brain, in this case.

#### SUMMARY

The case of a young man, 23 years of age, is reported. He suffered from a severe tremor at rest and a mild spastic hemiparesis involving the right extremities, from the age of eight years. The "arm" and "leg" portions of area 47, the posterior part of the precentral gyrus, were removed. This procedure completely abolished the tremor, produced considerable paralysis particularly of the hand and fingers, resulted in some increase in spasticity, caused no immediate disturbance in sensory perception, and was followed by excessive perspiration on the right half of the body for a few days. In this same case, at the time of the operation, the suppressor effect of area 4s was demonstrated for the first time in the human brain.

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## TRANSTHORACIC ESOPHAGOGASTROSTOMY FOR BENIGN STRICTURES OF THE LOWER ESOPHAGUS

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BENIGN OBSTRUCTION OF THE ESOPHAGUS, particularly at the lower end, may follow trauma, esophagitis; corrosion, simple peptic ulceration and chronic granulomas. Strictures of the esophagus associated with generalized scleroderma has been describe dby Lindsey, Templeton and Rothman.<sup>1</sup> In a certain number of cases no etiologic factor can be determined. In a series of 243 cases of benign strictures Vinson<sup>2</sup> found 40 of unknown origin. Strictures are less frequently observed than carcinomas or cardiospasm, but, as Yudin<sup>3</sup> pointed out, attract attention and interest because many of the cases concern young adults doomed either to repeated dilatations or to a miserable existence with a gastrostomy.

None of the five cases which form the basis of this report was considered to have cardiospasm. In one case the stricture followed the ingestion of lye, another was associated with generalized scleroderma,<sup>†</sup> and in three of the cases no etiologic factor could be ascertained. In all of the cases the obstruction either started above the diaphragm, or the entire lesion was in the thorax, so that none was amenable to a transabdominal cardioplasty.

It is said that stricture of the esophagus with complete anatomic stenosis seldom occurs and that gradual dilatation will eventually result in restoration of swallowing in most cases. In order to be successful, treatment requires the coöperation of the patient as well as skill and perseverance on the part of the physician.

It is that small group in which conservative treatment fails, that becomes of interest to the surgeon. Four of our cases had repeated dilatations, with only temporary relief, and two of these required gastrostomies when dilatations became impossible. The fifth case was not subjected to dilatation because a malignancy of the cardia was suspected.

In reviewing the literature, very little can be found concerning the surgical treatment of benign strictures of the lower esophagus. Yudin<sup>3</sup> recently has reported construction of an artificial esophagus in 80 cases of stricture of the esophagus. In six of these he used Birher's cutaneous method. Sixteen cases had a direct anastomosis of the pharynx to a jejunal transplant and 58 were operated upon by the combined methods, using a segment of jejunum for the lower part and a skin tube above.

Such procedures as Yudin describes may be applicable for strictures

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\* On active service with the United States Army.

† This case was previously reported by Lindsey, Templeton and Rothman.<sup>1</sup>

above the arch of the aorta but are certainly not ideal for lesions of the lower esophagus.

Transthoracic esophagogastrostomy was performed successfully on five cases of benign stricture of the lower esophagus. There were no deaths. Since review of the literature failed to reveal the use of such a procedure for lesions in this location, it was thought a report would be of interest even though the number of cases is small.

Most of the patients with a long-standing stricture of the esophagus are undernourished, which increases the possibility of postoperative complications. Adequate preoperative preparation is extremely important. Administration of fluid, whole blood and plasma will aid materially in enabling the patient to successfully undergo an operation. Four of the patients in our series were given sulfonamides preoperatively and one was digitalized (Case 4).

#### METHOD OF PROCEDURE

Positive pressure ethylene-oxygen-ether anesthesia administered through a snug-fitting face mask was used. The patients were placed on their right side with the left arm suspended from a rectangular frame. The left chest and the abdomen were prepared for operation, and an ankle vein was prepared for intravenous injection. The chest was opened through the eighth rib bed in four cases and through the eighth interspace in one case. Excellent exposure was obtained by the latter approach without resecting any ribs. The lung was retracted mesially and anteriorly, exposing the costovertebral gutter. In the first three cases, the phrenic nerve was crushed, but in the last two cases a long segment of the phrenic nerve was excised in order to assure a permanent paralysis of the diaphragm. The mediastinal pleura was incised and the lower esophagus isolated, including the accompanying vagi, which were spared wherever possible. In our experience, the lesion was very difficult to identify, and only after very careful inspection and palpation was it possible to determine the level and extent of the stricture. A 12-cm. radial incision was made in the diaphragm from the periphery toward the esophageal hiatus. The left phrenic artery was divided and ligated. In two of the cases the spleen was removed to facilitate mobilization of the stomach. Usually the fundus of the stomach could be brought up readily into the thorax to the arch of the aorta after the upper part of the greater curvature of the stomach had been liberated. The site for anastomosis was selected just above or at the upper level of the stricture. Two umbilical tapes were placed around the esophagus and tied twice, the second tie being a slip-knot, as shown in Figure 1. A side-to-side anastomosis was then made between the fundus of the stomach and the esophagus with two rows of interrupted or continuous linen sutures (Fig. 1). Tension on the suture line was relieved by anchoring the stomach to the pleura above the anastomosis. The diaphragm was closed about the stomach and sutured to its wall. A Pezzar catheter was inserted posterolaterally through the ninth interspace for pleural drainage. The wound was closed

tightly. Blood transfusion was given in every case and was started at the beginning of the procedure. From 600 to 1,800 cc. were administered. The operations required from two to four hours.

#### POSTOPERATIVE COURSE AND CARE

All of the patients made an uneventful recovery and are still alive and enjoying a normal existence. Four of the cases received sulfonamides intravenously and one (Case 5) was given penicillin intramuscularly. Small amounts of liquids were given *per os* on the fifth to the seventh day, following which the diet was gradually increased. By the tenth to the twelfth day each was taking a soft diet without difficulty. None complained of regurgitation, even at night. The pleural drainage catheter was removed on the fifth to the seventh day.

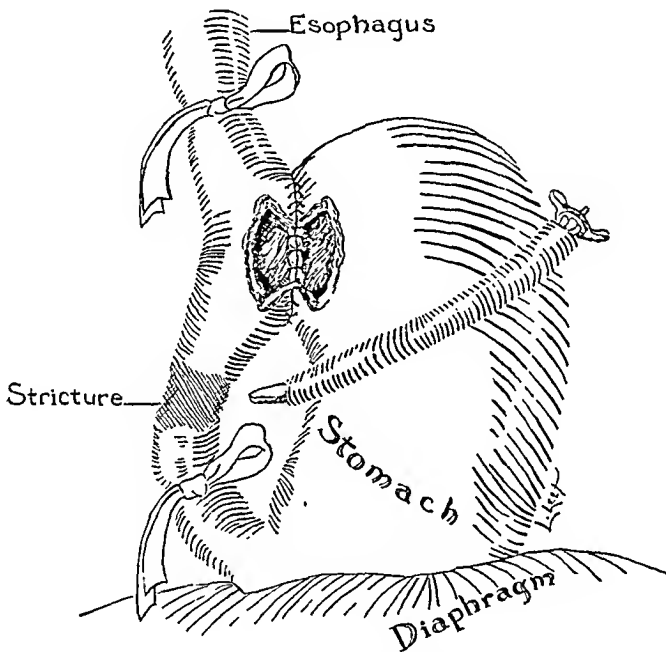


FIG. 1.—Diagram showing side-to-side esophagogastrostomy above the level of the benign stricture.

#### CASE REPORTS

Case 1.—P. V., a male, age 26, was admitted to the hospital, September 6, 1941, complaining of difficulty in swallowing which had begun approximately three years previously. Liquids as well as solid foods seemed to stick beneath the sternum, and he obtained relief only after most of the ingested food had been regurgitated. He had lost 45 pounds of weight during the three-year period. Two years before admission a diagnosis of a stricture of the lower esophagus was made, and repeated dilatations were performed, which would give him relief for one to two days. Antispasmodics afforded him very little benefit. No etiologic factor could be ascertained. Past history, family history and social history were not significant.

Physical examination revealed a well-developed young man with obvious signs of



considerable weight loss. The blood pressure was 112/70. Detailed examination revealed no abnormal findings.

Laboratory examinations showed white blood count 8,600; hemoglobin 12.8 Gm.; and red blood count 4,400,000. Wassermann and Kahn tests were negative. Urine was negative. Roentgenologic studies of the esophagus following the ingestion of barium revealed a stricture of the lower esophagus which began about two centimeters above the diaphragm (Fig. 2).

The patient was very despondent and refused dilatations or any form of conservative therapy. On September 9, 1941, a transthoracic esophagogastrostomy was performed. His recovery was uneventful, and he was discharged on the 13th postoperative day. Roentgenograms of the esophagus and stomach after the ingestion of barium made on the day of his discharge revealed a well-functioning esophagogastrostomy (Fig. 3).

Within a few months he had regained all of his lost weight and was able to eat any food without experiencing any difficulty.

**Case 2.**—S. S., age 40, was admitted to the clinics August 1, 1942. He complained of progressive difficulty in swallowing for seven years. Dilatation was first undertaken two years after the onset of dysphagia and was repeated at irregular intervals, with only temporary relief until December, 1941. At this time the obstruction became almost complete and dilatation was unsuccessful. A gastrostomy was performed, through which he received all of his nourishment. Retrograde dilatations were attempted with the aid of a string in the esophagus but these were, likewise, unsuccessful. He had lost 47 pounds of weight and had become quite weak.

About 1.5 years after the onset of the dysphagia, the skin on his hands, feet and face began to tighten and become atrophic. The condition became progressively worse, and he developed repeated ulcers on his fingers which healed very slowly. Past history was irrelevant.

Physical examination showed a fully developed, easily recognizable, generalized scleroderma, with the characteristically stiff and atrophic appearance of the face and the hands (Fig. 6). There was a large gastrostomy opening in the upper abdomen into which a large rubber tube was inserted. Considerable gastric juice leaked from around the tube and the skin on the upper abdomen was markedly excoriated.

**Laboratory Data:** White blood count 6,850; hemoglobin 13.5 Gm.; red blood count 3,870,000. Urine was negative, Wassermann and Kahn tests were negative. Blood chemical determinations were all within normal limits. B.M.R. was plus 1. Roentgenologic examination of the esophagus revealed a smooth narrowing 2 to 3 cm. in length just above the phrenic ampulla (Fig. 4). The barium passed slowly through the stricture. A primary peristaltic wave began in the pharynx and progressed only a short distance



FIG. 2.—Case 1: Roentgenogram of the esophagus and stomach following the ingestion of barium showing a marked narrowing of the lower esophagus. The stricture begins about 2 cm. above the diaphragm.

down the esophagus to the level of the sternal notch where it disappeared. A shallow contraction wave continued on down. This wave was not powerful enough nor deep enough to force a bolus ahead of it. No tertiary waves were seen.

At esophagoscopy, the wall of the esophagus from the middle third downward was diffusely reddened and apparently thickened. In the lower third, a diffuse layer of white exudate was present which could be easily separated off, leaving a granulating base. At a distance of 40 cm. from the upper teeth a smooth scar tissue constriction

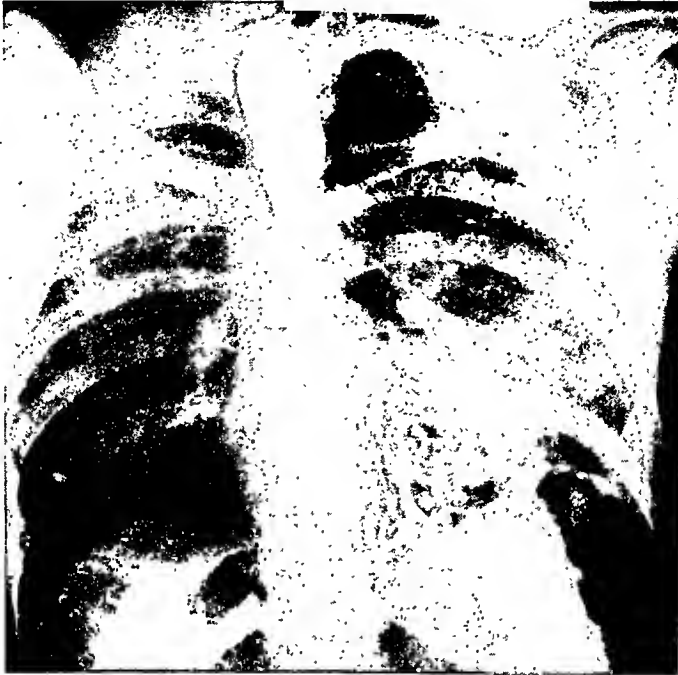


FIG. 3.—Case 1: Roentgenogram of the esophagus and the stomach, 13 days after transthoracic esophagogastrostomy. The site of anastomosis is well shown. The proximal one-fourth of the stomach is in the thorax. Fluoroscopy revealed no obstruction.

was present which did not admit the esophagoscope. There was superficial ulceration in and above the area of the stricture which became apparent when the layer of exudate was removed. A string was present in the esophagus.

In view of the excellent results obtained in the first case it was decided to perform a similar procedure on this patient in spite of the severe changes due to the generalized scleroderma. On September 26, 1942, a transthoracic esophagogastrostomy was performed. A constriction was found approximately 2.5 cm. above the diaphragm. The wall of the esophagus above the narrowing was considerably thickened. He made an uneventful recovery. The gastrostomy was closed one month after the esophagogastrostomy.

Roentgenograms of the esophagus and stomach following the ingestion of barium two weeks postoperatively showed a well-functioning esophagogastrostomy, with no obstruction to the flow of barium (Fig. 5). The physiology of the esophagus was not changed.

COMMENT: Many patients with scleroderma develop benign strictures of the esophagus. Dilatation is difficult because these patients cannot open their

mouths more than one-half the normal width, protrusion of the tongue is limited, and the head cannot be placed satisfactorily because of tightness of the skin over the jaws and neck.

Even though most of the patients with scleroderma and dysphagia show a marked disturbance in the physiology of the esophagus, transthoracic esophagogastrostomy certainly offers them a more comfortable life than a gastrostomy. The pathologic changes in the esophagus did not seem to impair healing.

**Case 3.**—Mrs. L. L., age 35, was admitted to the University Clinics October 4, 1943. About 19 years previously she had ingested lye. Two months later she began to have dysphagia which gradually became worse until she had difficulty in swallowing even liquids. A diagnosis of a stricture of the lower end of the esophagus was made, and for eight months she was given weekly dilatations. For the next three years she got along well, after which time she again began to have marked difficulty in swallowing solid foods. During the succeeding eight years she required regular periods of dilatation. As time went on she obtained less improvement from each dilatation. Seven years ago a gastrostomy was performed through which she received most of her nourishment. Since the onset of her dysphagia, she has always been undernourished and weak. Past history was not significant.

Physical examination revealed a very thin woman, who appeared chronically ill. A gastrostomy opening was present in the upper abdomen through which a large rubber tube protruded. The skin over the upper abdomen was excoriated.

Laboratory studies were normal.

Roentgenologic examination of the esophagus after the ingestion of barium demonstrated a high-grade stricture of the esophagus beginning about 11 cm. above the diaphragm and extending downward for a distance of approximately 7 cm. The esophagus above the stricture was somewhat dilated (Fig 7).

On October 10, 1943, a transthoracic esophagogastrostomy was performed. The lower 8 cm. of the esophagus was firmer and thicker than normal, although the exact extent of the lesion was not distinct.

The patient's postoperative convalescence was uneventful. A roentgenologic study of the esophagus with barium at the time of her discharge showed a well-functioning anastomosis between the fundus of the stomach and the lower esophagus (Fig. 8).

The gastrostomy was closed six weeks after the esophagogastrostomy.

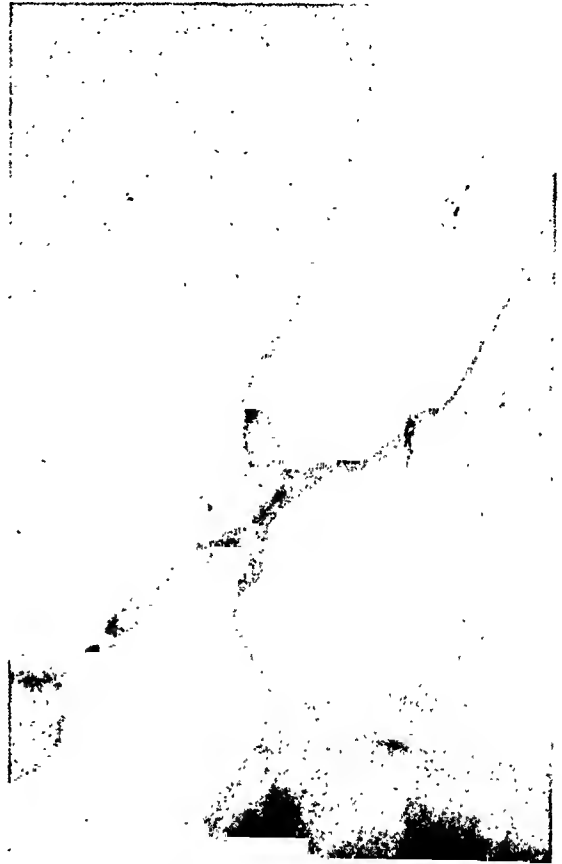


FIG. 4.—Case 2: Benign stricture of the esophagus just above the phrenic ampulla associated with generalized scleroderma.

Three months after the operation the patient was eating normally and had gained 50 pounds. There was no apparent regurgitation of gastric contents into the esophagus.

**Case 4.**—Mrs. M. B., age 60, was admitted to Albert Merritt Billings Hospital, May 6, 1944, complaining of difficulty in swallowing for a period of five months. The dysphagia was intermittent and began after an attack of influenza. Solid food caused



FIG. 5.—Case 2: Roentgenogram of esophagus and stomach following the ingestion of barium, two weeks after transthoracic esophagogastrostomy. A wide anastomosis is shown. The proximal one-third of the stomach is above the diaphragm.

her more discomfort than liquids. Food seemed to stick just beneath the lower sternum. She had some regurgitation, but at other times she would have the sensation of something releasing and her discomfort would disappear. Nervousness or emotional excitement made her condition worse. She had lost 23 pounds in weight and had become quite weak. Past history was irrelevant.

Physical examination was negative except for the obvious evidence of recent weight loss.

Laboratory data disclosed a white blood count of 7,900, with a normal differential; hemoglobin 13.5 Gm.; red blood count, 4,270,000. The urine was negative. Plasma proteins were 6.38 Gm. per cent. Gastric analysis after the administration of histamine revealed free acid in all specimens.



FIG. 6A

FIG. 6.—Case 2: Photograph of hands and face showing the typical changes of advanced generalized scleroderma.

Roentgenologic study of the esophagus and stomach after the ingestion of barium showed a marked narrowing of the lower esophagus which began just above the diaphragm. Under the influence of amyl nitrite the narrowed area dilated to 1 cm. A filling defect was observed in the cardia of the stomach, and was interpreted as a possible malignancy of the stomach (Fig. 9).

On May 19, 1944, the proximal portion of the stomach and the lower esophagus was explored through a transthoracic approach. The filling defect observed at fluoroscopy was found to be caused by redundant mucosa. An esophagogastrostomy was performed, connecting the fundus of the stomach to the lower esophagus.

The patient made an uneventful post-operative recovery, and was completely relieved of her dysphagia. Roentgenograms, taken June 5, 1944, revealed a well-functioning esophagogastrostomy.



FIG. 6B

COMMENT: Dilatation was not attempted on this patient because of the possibility of malignancy being present. The transthoracic approach was used because it afforded better exposure to the portion of the stomach suspected of having malignant involvement, and it offered a better means of dealing with direct extension into the lower esophagus.

This patient received digitalis preoperatively. Patients in the upper age-group tolerate such surgery much better if they have been digitalized. No adverse reactions have been observed.

Case 5.—J. B., male, age 38, was first seen at the University of Chicago Clinics June 16, 1944. Eight weeks before this date he suddenly began to have difficulty in swallowing solid foods. This difficulty gradually progressed and for two weeks prior



FIG. 7.—Case 3: Shows a long cicatricial stricture of the lower esophagus following corrosion from swallowing lye. The obstruction is almost complete.

to admission he was unable to swallow even liquids. The ingested food seemed to stick beneath the lower sternum, and then it would be regurgitated. He had lost 28 pounds of weight. Past history revealed that he had swallowed a fish bone ten years ago which caused some dysphagia for about two weeks.

Physical examination showed nothing remarkable except for the obvious signs of recent weight loss and dehydration.

Laboratory data showed a white blood count 6,050; hemoglobin 12.5 Gm.; red blood count 3,790,000. Urine negative. Wassermann and Kahn negative. Roentgenologic examination of the esophagus after the ingestion of barium showed an obstruction at the junction of the middle and lower thirds of the esophagus. The obstructing lesion was about 0.5 cm. in length (Fig. 10).



FIG. 8.—Case 3: Roentgenogram of the esophagus and stomach after the ingestion of barium, two and one-half weeks after transthoracic esophagogastrostomy. There is a well-functioning anastomosis and no obstruction to the flow of barium.



FIG. 9.—Case 4: Roentgenogram of lower esophagus and upper stomach after ingestion of barium showing a marked narrowing of the lower esophagus which begins just above the diaphragm. Obstruction is not complete. Irregularity along the fundus was interpreted as possibly due to a carcinoma of the stomach.



FIG. 10.—Case 5: Roentgenogram of lower esophagus after the ingestion of barium showing narrow stricture 8 cm. above diaphragm. Obstruction is almost complete.

The patient was esophagoscoped three times within eight days. A stenosis was observed approximately 8 cm. above the diaphragm. The esophagoscope could easily be passed through the stenosed area, but when it was withdrawn the cicatricial region would snap closed. A No. 20 dilator was passed at the time of each esophagoscopy. Two biopsies removed from the region of the stricture showed chronic inflammation. The patient's dysphagia was not relieved by the dilatations, and he had to be given parenteral fluids daily.

On June 16, 1944, a transthoracic esophagogastrostomy was performed. There was considerable reaction in the mediastinum about the area of stenosis. The lower limit

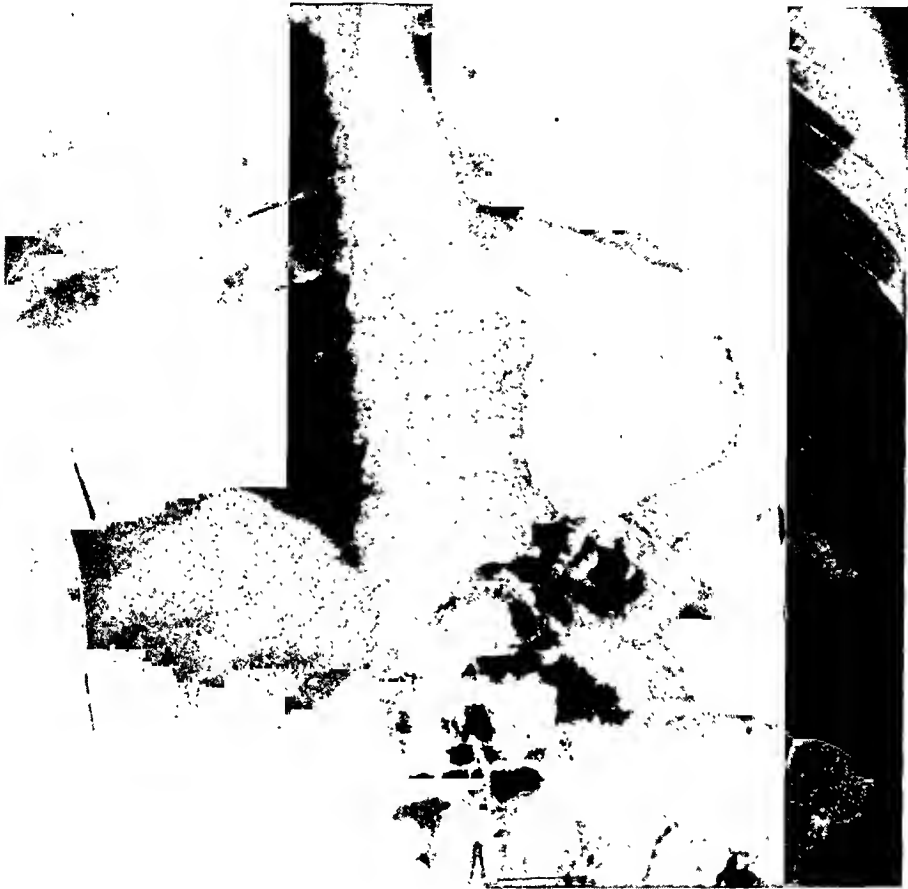


FIG. 11.—Case 5: X-ray eleven days after transthoracic esophagogastrostomy. A wide, well-functioning anastomosis is seen. The esophagus below the stricture is visualized. The proximal one-half of the stomach is in the thorax.

of the anastomosis was made in the stricture. Biopsy obtained from the involved area at the time of operation showed chronic inflammation.

The patient made an uneventful recovery. Roentgenographic study of the esophagus and stomach, which was made on the day of his discharge, showed a well-functioning esophagogastrostomy. Since the stricture was relieved by the operation, the barium flowed readily through the lower esophagus (Fig. 11).

COMMENT: In some cases, even after repeated esophagoscopies and roentgenologic studies, it is difficult to distinguish a benign lesion from a stricture caused by a neoplasm. In such cases the stenosed area should be opened and a biopsy obtained.



SUMMARY

1. Five cases of transthoracic esophagogastrostomy for benign stricture of the lower esophagus are reported. There were no deaths.
2. In selected cases of benign stricture of the lower esophagus, transthoracic esophagogastrostomy offers the patient complete relief of symptoms without the necessity for repeated dilatations or the unpleasantness of a gastrostomy.
3. The technic of the operation is discussed.

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# THE USE OF PENICILLIN IN THE TREATMENT OF ACUTE HEMATOGENOUS OSTEOMYELITIS IN CHILDREN

## REPORT OF TWELVE CONSECUTIVE CASES

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ACUTE HEMATOGENOUS OSTEOMYELITIS is caused, in most cases, by *hemolytic Staphylococcus aureus* or *albus*, or *hemolytic Streptococcus* organisms. Most of the patients are children and, hence, the bones that are involved are growing.

Cases of acute hematogenous osteomyelitis should be divided into age-groups for purposes of discussion or statistical analyses: (1) Under three years of age. (2) Ages three to 14 years. (3) Fourteen to 20 years. (4) Adults.

In very young children the infecting organism is more often the streptococcus. The initial infection may be in the nose, throat, middle ear, vaccination wound, or in the umbilicus of a newborn infant. This organism does not produce as extensive destruction of bone as does the staphylococcus. Furthermore, the bones of infants repair quickly and persistent drainage or extensive sequestration is less common than in older patients.

Hematogenous osteomyelitis in children, age three years to puberty, is secondary in most cases to some small area of infection in the skin, such as a furuncle. Bacteriemia or septicemia may result and lead to localization in one or many bones. When bacteriemia becomes septicemia abscesses may occur in various organs of the body as well as in the osseous tissues. The prognosis for recovery without the development of chronic osteomyelitis is not as favorable in the child over three years of age as it is in the infant patient.

The treatment of acute osteomyelitis by means of various sulfonamide compounds has been of proved value. However, some patients have been found sensitive to the sulfonamides and in others the infecting organism was sulfa-resistant. Many patients so treated, with apparent success, subsequently developed sinuses and required surgery for the removal of sequestra or partial osteotomy for drainage of bone abscesses. Although the value of penicillin in the treatment of infections of bones following compound fractures, paranasal sinus suppuration, and in chronic osteomyelitis has been fairly well-established, few case reports of its use in acute hematogenous osteomyelitis have been made.

In each of the 12 cases which we are reporting, the acute infection was controlled by the use of penicillin, or a combination of penicillin and sulfonamides. In none of the 12 cases was surgery resorted to during the acute

illness after beginning penicillin therapy. Two of the 12 patients had been subjected to surgery prior to the administration of penicillin, and three were subsequently operated upon: one for the removal of a small sequestrum, a second, for removal of a sequestrum and later drainage of a small abscess, and a third, for the drainage of an abscess. These operations were performed months after the acute illness. All of the patients have been under observation for a period of five months or longer. Of the 12 patients included in this study, the youngest was just over three years of age and the oldest were two patients 12 years of age.

The focal infections included four femora, three tibiae, one humerus, one ischium, one cuneiform bone of the foot, one patella and femur, and one calvarium. In the latter case, however, the patient had been treated 15 months before for acute, hematogenous osteomyelitis of the left femur by means of sulfathiazole. In spite of this treatment, which was combined with surgery for drainage, several new foci appeared during the succeeding 12 months. The osteomyelitis of the skull, which represented a new focus, was successfully treated with penicillin, after obtaining a blood culture which was positive for *hemolytic Staphylococcus aureus*. The acute lesion in the skull healed without requiring surgical drainage. No new lesions which produced clinical symptoms appeared from October, 1943, to July 25, 1944, at which time the child was examined and found to be entirely well. The 12 cases which make up this report represent all of the acute hematogenous osteomyelitis patients which were admitted to our service, or seen by us in consultation, at the Children's Memorial Hospital,\* in Chicago, between July, 1943, and March 1, 1945.

#### CASE REPORTS

##### Case 1.—*Acute Osteomyelitis of Skull with Meningitis.*

R. C., born April 2, 1937, white, male, entered Children's Memorial Hospital, July 9, 1942, acutely ill and complaining of pain in the left leg. A diagnosis of acute osteomyelitis of the left femur was made and treatment with sulfathiazole was started. July 16th, the abscess was drained and a hip spica was applied. Between July 16th and August 19th, 1943, the patient had new foci develop in the left ulna, right sacrum, and left humerus.

On October 18th, he complained of a severe headache, dizziness and vomiting. When he was examined at the Children's Memorial Hospital two days later he was found to be acutely ill, with a red pharynx, a markedly rigid neck, and a red tender area over the frontal bone. The spinal fluid was cloudy, the Pandy test was three plus, there were 4,000 cells, chiefly polymorphonuclear leukocytes, in each cubic centimeter, and gram-positive organisms. Roentgenograms showed osteomyelitis of the left frontal region of the skull. Both the blood culture and spinal fluid culture were positive for *hemolytic Staphylococcus aureus* organisms.

Twenty-five thousand units of penicillin in 500 cc. of normal saline solution were given intravenously at the rate of 15 drops per minute throughout the first day. Penicillin was then administered intramuscularly every three hours. Recovery was uneventful and healing complete.

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\* We are indebted to both the Medical and Surgical Services of the Children's Memorial Hospital and especially to Dr. Stanley Gibson, Chief of Staff, for the privilege of observing patients under their care and of following the course of the disease.

The patient was last seen on November 28, 1944. The lesions had remained healed, and there have been no recurrences.

A total of 500,000 units of penicillin was used in the treatment of this case.

**Case 2.—*Acute Osteomyelitis of the Right Femur.***

R. G., born December 23, 1940, white, male, entered Children's Memorial Hospital December 21, 1943. Following an upper respiratory infection he had begun complaining of pain in the right arm, right chest, and subsequently the right thigh and leg. Physical examination revealed a slender, well-developed child, who was not acutely ill. Minimal swelling and redness were present in the right thigh. There was limitation of internal and external rotation of the hip. Blood culture was positive for *Staphylococcus aureus*. Roentgenograms confirmed the impression of osteomyelitis of the femur (Fig. 1). Sulfathiazole grains 7.7 every four hours was started. On December 27th, the temperature was still high and swelling in the right thigh had increased. Sulfathiazole was discontinued and penicillin was started (Fig. 2). There was a good response to this treatment. However, the destruction of bone made it advisable to protect the femur and, on January 22, 1944, a hip spica plaster encasement was applied. On January 12, 1945, nearly a year after the acute illness, a small sequestrum was removed. Prompt healing followed. March 31, 1945, a small fluctuant area in the scar was incised and a moderate amount of purulent material was expressed. The general health and physical condition of this patient is now satisfactory, and the local lesion has remained healed.

A total of 495,000 units of penicillin was used in the treatment of this case.

**Case 3.—*Acute Osteomyelitis of the Right Humerus.***

D. D., born April 8, 1932, white, male, became ill on May 7, 1944. On the following day he complained of pain in his shoulder. During the next few days he became progressively more septic, with restlessness, and at times delusions.

He was seen at Children's Memorial Hospital on May 12th, and was found to have a swollen, painful right shoulder. The blood culture was positive for *Staphylococcus aureus*. Sulfathiazole, grains 7.7, every four hours was administered for two days. On the seventh day of the illness penicillin, 10,000 units intramuscularly every three hours, was started and four days later the dose was increased to 25,000 units every four hours. An encasement to splint the arm was applied on June 1st (20th hospital day) (Figs. 3 and 4).

The patient was last seen on April 5, 1945. There were no sinuses or deformities of the arm, and function was normal in every respect.

A total of 2,310,000 units of penicillin was used in the treatment of this case.

**Case 4.—*Acute Osteomyelitis of the Right Femur.***

J. T., born September 20, 1932, white, male, entered Children's Memorial Hospital on May 24, 1944. May 19th he had developed pain in both his legs and his ankles had become swollen and painful. On May 31st, swelling and tenderness were marked over the distal third of the right femur. Roentgenograms showed a destructive process just proximal to the distal right femoral epiphysis. Swelling and tenderness persisted and the knee became held in 90 degrees of flexion. Twenty thousand units of penicillin were administered intramuscularly every four hours. Clinical improvement was rapid.

A total of 840,000 units of penicillin was used in the treatment of this case. Recovery was complete.

**Case 5.—*Acute Osteomyelitis of the Right Upper Femoral Metaphysis.***

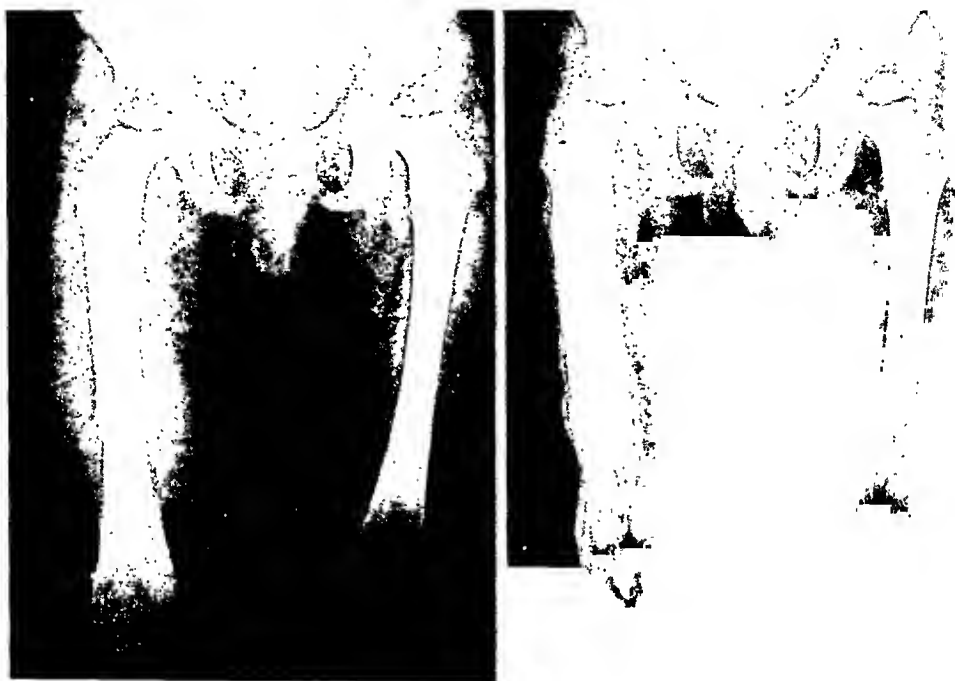
A. M., born September 9, 1933, white, female, entered Children's Memorial Hospital, July 4, 1944, with the complaint of severe pain in the right hip on weight-bearing. There was swelling of the right hip region, inability to rotate the hip, and tenderness posteriorly over the trochanter and the inguinal region. A sulfonamide drug had been administered by the family physician for three days prior to coming to the hospital. Blood culture showed no growth. Roentgenograms showed very slight bone destruction in the region of the greater trochanter (Fig. 5). The right leg was placed in Buck's

traction, and 100,000 units of penicillin per day were given. Recovery was uneventful (Fig. 6).

A total of 1,360,000 units of penicillin was used in the treatment of this case.

**Case 6.—*Acute Osteomyelitis of the Right Ischium.***

D. M., born January 2, 1934, white, male. A furuncle was noted on the medial aspect of the left knee July 6, 1944. On July 10th he began to limp, the temperature was 103° F., and the following day 105° F. A physician prescribed a sulfonamide drug. There was no improvement, and July 20th he was brought to the Children's Memorial Hospital. Roentgenograms revealed osteomyelitic involvement of the right ischial bone (Fig. 7). Blood culture showed *nonhemolytic Staphylococcus*. Bone destruction continued (Fig. 8). Five doses, 20,000 units each, of penicillin were given intramuscularly every 24 hours.



A. 17th day after admission. B. 30th day after admission.  
FIG. 1.—Case 2: R. G.: Roentgenograms showing the extensive destruction of the shaft of the femur.

An examination two months after discharge from the hospital showed the patient to be clinically normal.

A total of 1,020,000 units of penicillin was used in the treatment of this case.

**Case 7.—*Acute Osteomyelitis of the Left Femur.***

LeR. B., born July 23, 1933, white, male, entered Children's Memorial Hospital, July 31, 1944, with the complaint of pain in his left thigh for five days. He had been unable to walk for four days and the evening temperature was high. Sulfathiazole was given for one day only. Penicillin was started, 12,500 units every three hours, and the recovery was rapid. On August 11, 1944, the penicillin was reduced to 6,000 units every three hours and was stopped on August 15, 1944. Changes in the architecture of the femur were minimal as shown in the roentgenograms. A small abscess developed four months later, in December, 1944, and this was operated upon January 15, 1945. *Staphylococcus aureus* was obtained in the culture of the abscess material. The wound healed promptly after the operation. The last examination was on April 5, 1945. The patient was then clinically well.

A total of 1,425,000 units of penicillin was used in the treatment of this case during the acute attack.

**Case 8.—*Acute Osteomyelitis of the Right Tibia.***

W. S., born May 24, 1937, entered Children's Memorial Hospital on August 29, 1944. August 23rd a large boil on the left elbow had been lanced by the family physician. The right foot became very painful four days later, and he was not able to walk on it. His temperature was 102° F. He was given sulfonamides for two days, but the pain localized just above the ankle and he was admitted to Children's Memorial Hospital for treatment. Physical examination revealed a tender, red swelling in the distal third of the right leg. One hundred thousand units of penicillin were given intramuscularly every 24 hours for four days. Improvement was immediate and the penicillin was reduced to 80,000 units every 24 hours for the next six days, then 60,000 units every 24 hours for three days. Recovery was complete.

A total of 960,000 units of penicillin was used in the treatment of this case.

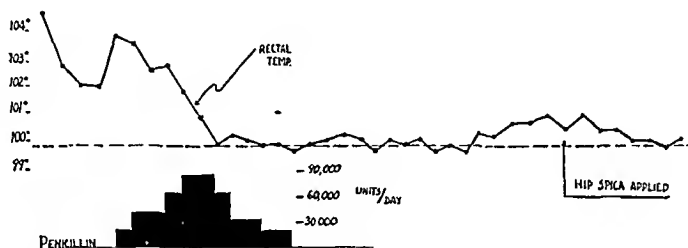


FIG. 2.—Case 2, R. G. Chart showing response to penicillin therapy.

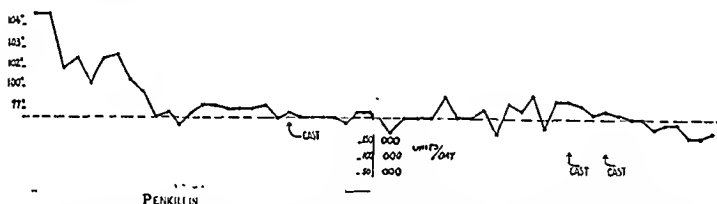


FIG. 3.—Case 3, D. D.: Chart of temperature (heavy line—rectal temperature) W. B. C., and penicillin (total units given per day).

**Case 9.—*Acute Osteomyelitis of the Tarsal Bones of the Right Foot.***

M. G., born October 18, 1936, white, female, complained October 12, 1944, of pain in the right foot upon weight-bearing. October 18, 1944, she developed a septic temperature. Sulfathiazole was begun and continued until admission to Children's Memorial Hospital. October 23rd there was a fluctuating mass, and the abscess was opened.

She was transferred to Children's Memorial Hospital December 5, 1944. The right foot was red, swollen, and there were four or five draining sinuses. Her rectal temperature on admission was 100.4° F. Penicillin, 12,500 units intramuscularly every three hours, was started December 6th and continued for 17 days. Sulfathiazole, which had been stopped upon admission, was started again December 7th and continued for 16 days. Culture of the draining sinus and blood culture were positive for *Staphylococcus hemolyticus aureus*.

The clinical course was satisfactory. A sequestrectomy of the first cuneiform bone of the right foot was performed January 13, 1945, and the wound healed promptly.

When examined March 8, 1945, the wound was closed, and recovery was complete.

During the course of this disease the patient received approximately 141 Gm. of sulfathiazole before and 48 Gm. after her admission to Children's Memorial Hospital.

**Case 10.—*Acute Osteomyelitis of the Left Lower Tibia.***

F. W., born June 10, 1940, white, male, complained of pain, and redness and swelling of the left ankle and foot were noted November 13, 1944. Sulfadiazine, 1 Gm. three times a day, was administered for one week. He was admitted to Children's Memorial

Hospital November 18. There was swelling, pain, and increased heat extending distally from the midtibia to the ankle and the dorsum of the foot. Blood culture showed no growth. A diagnosis of osteomyelitis of the left lower tibia was made. Penicillin, 100,000 units per day intramuscularly at three-hour intervals, was started and continued for ten days. On the third hospital day he received 3 Gm. of sulfathiazole. On the sixth hospital day he received a 150 cc. whole blood transfusion. Clinical improvement was satisfactory and on the 11th hospital day the dosage of penicillin was reduced to 10,000 units intramuscularly every four hours.

He was discharged on the 26th hospital day. The tenderness and swelling had disappeared. Motion and function of the ankle joint were normal.

The total amount of penicillin administered was 1,480,000 units.

**Case 11.—Acute Osteomyelitis of the Left Patella and Distal End of Femur.**

R. F., born March 15, 1939, white, male, was admitted to Children's Memorial Hospital January 17, 1945. His left knee was swollen, red, hot and tender. There was superficial venous engorgement over the thigh, and thickening over the metaphysis of the femur. Effusion into the knee joint was present. There was exquisite tenderness over the patella. Blood culture was not obtained. Sulfathiazole, 3 Gm. per day, was started upon admission, and on the first hospital day 15,000 units of penicillin every four hours was started. Sulfathiazole was discontinued on the 15th hospital day; penicillin was reduced on the tenth hospital day to 50,000 units intramuscularly each 24 hours, and was discontinued on the 16th hospital day.

He was last examined on April 12, 1945, and at that time was considered to be fully recovered.

This patient received 45 Gm. of sulfathiazole in 15 days and, concurrently, 1,300,000 units of penicillin.

**Case 12.—Acute Osteomyelitis of the Left Tibia.**

A. K., born January 14, 1934, white, male, complained of pain in the left ankle March 2, 1945, and his temperature was 105° F. He was admitted to Children's Memorial Hospital, March 3, 1945, and a diagnosis of osteomyelitis was made, although roentgenographic changes in the bone were still indefinite. One hundred thousand units of penicillin were administered intramuscularly each day in doses of 12,500 units every three hours for 11 days. He was discharged on the 13th hospital day.

When examined on April 12, 1945, he was entirely well.

The prognosis in the treatment of acute hematogenous osteomyelitis in childhood, as indicated by reports of various observers, was most discour-



FIG. 4.—Case 3, D. D.: This roentgenogram of June 20, 1944, the 39th day of hospitalization, shows the extent of the destructive process and the amount of involucrum formed.

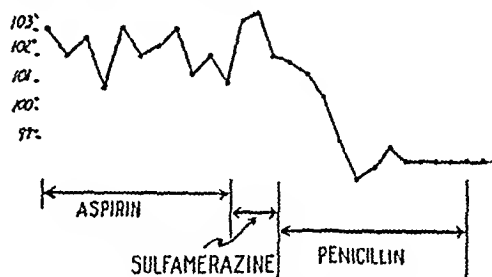


FIG. 5.—Case 4, J. T.: Chart of the hospital course and treatment.

aging prior to the development of chemical agents to which the organisms producing this disease have proved to be susceptible. Too frequently surgery was resorted to without first preparing the patient by a program of rest, blood transfusions, and correction of the body fluid balance. Extensive surgical procedures were occasionally recommended and instituted when the patient was critically ill, and these no doubt increased the mortality rate. Dickson<sup>1</sup> states that the average mortality "as nearly as can be determined in

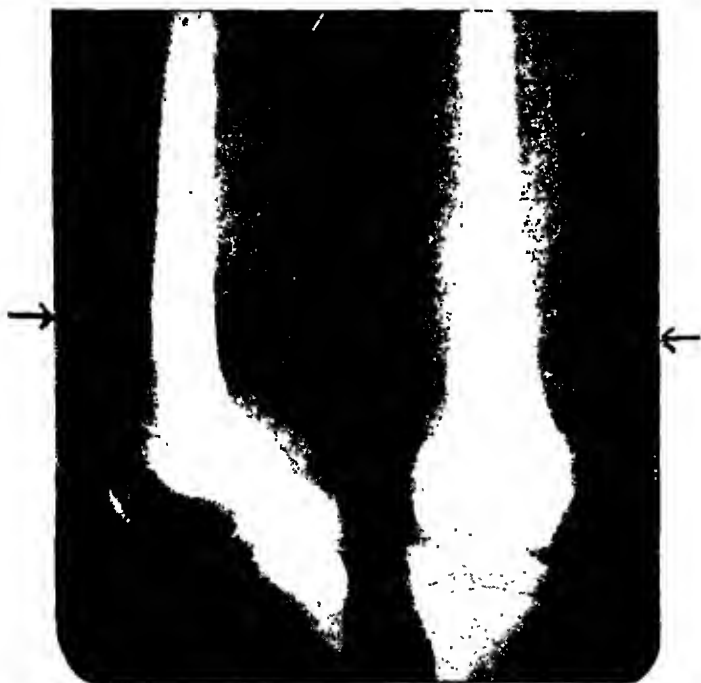


FIG. 6.—Case 4, J. T.: Roentgenogram of the femur made 27 days after admission to Children's Memorial Hospital.

the usual type of the disease is somewhere around 10 to 15 per cent. The mortality in the septicemic type is well over 50 per cent; perhaps higher."

The results of penicillin therapy in a few reported cases,<sup>2, 3, 4</sup> and in this series of 12 consecutive cases of acute hematogenous osteomyelitis have included no deaths; no extensive areas of chronic osteomyelitis; and no instance of multiple foci in the bones after such treatment had been started. Three of these patients were critically ill, and in five of the patients (Cases 1, 2, 3, 6 and 9) blood cultures were positive for *Staphylococcus aureus*. Hemolytic *Staphylococcus aureus* was also cultured from the spinal fluid of Case 1. Negative blood culture in other cases may be attributed, in part, to the length of the elapsed time between onset and admission to Children's Memorial Hospital, and, in part, to sulfonamides which had already been administered.

The question of whether or not initial drainage should be carried out in each case of acute hematogenous osteomyelitis is still a controversial issue. Dickson<sup>1</sup> favors early drainage of the osseous focus except in the fulminating type. Wilson and McKeever,<sup>5</sup> as well as Dickson, reported that patients



treated with the sulfonamides without initial drainage frequently had more bone destruction and required greater surgical interference later than did those cases in which surgical drainage was instituted during the acute stage of the disease. The response to penicillin therapy in the short series of cases which we are reporting encourages us in the opinion that penicillin will prove to be a more effective chemotherapeutic agent for this disease than were the sulfonamides.

In the short series of cases reported here, sulfonamides had proved to be



FIG. 7.—Case 6, D. M.: Roentgenogram of July 27, 1944. (17th day of illness).

of little value in those cases in which they were employed before penicillin was started. Almost immediate response to penicillin therapy was noted in the rapid lowering of the temperature of the acutely ill patients. The failure of the disease to spread to other bones or other organs in any of our patients, encourages us to hope that if penicillin could be started immediately



FIG. 8.—Case 6, D. M.: The above chart is the hospital summary of this case.

after the onset of the acute illness, abscess formation, spread of infection in the bone that is involved, or devitalization of bone and the formation of sequestra may become relatively uncommon sequelae of acute osteomyelitis in children. Late surgery, which has been necessary for the removal of sequestra or the drainage of bone abscesses, may be rarely necessary. Since the bacterial organisms which produce more than 95 per cent of the cases of acute hematogenous osteomyelitis in children are susceptible to penicillin, while some of them are resistant to the sulfonamides, the use of penicillin should be a *must* when this disease is diagnosed.

## CONCLUSIONS

1. Twelve cases of acute hematogenous osteomyelitis in children, age three to 12 years, have been studied and reported.
2. Penicillin was employed successfully in the treatment of each of the 12 patients.
3. The infection in ten of the patients treated successfully by penicillin had proved to be resistant to the sulfonamides.
4. Surgery was necessary in four of the 12 patients: in one, for the removal of a small sequestrum, and in three, for the drainage of an abscess after the acute infection had subsided.
5. Penicillin appears to be a more effective agent in the treatment of acute hematogenous osteomyelitis than has any other therapeutic agent, including the sulfonamides.
6. Early use of penicillin in adequate doses administered at frequent intervals may not only cure the initial infection but prevent spread to other bones and in a majority of cases make surgery unnecessary.
7. If the penicillin is not started until after a bone has been extensively damaged, with necrosis of segments of cortex, central destruction of bone, and cavity formation, late surgery may become necessary.
8. From our experience in this short series of cases, we hazard the suggestion that in children, age three to 12 years, acute hematogenous osteomyelitis may be effectively treated if penicillin is administered intramuscularly in doses of 15,000 to 20,000 units each every three hours day and night. After the temperature begins to subside, the size of each dose may be reduced to 10,000 units, but the frequency of dosage must be maintained. When the patient becomes afebrile the dosage may be reduced gradually and discontinued after five days of normal temperature. Recurrences may occur if penicillin is stopped too soon. In several cases, there was a small, secondary temperature rise after stopping the penicillin.
9. While making use of a remarkable chemotherapeutic agent such as penicillin, we must not neglect to use well-established principles of medical care, such as the maintenance of the fluid balance of the body through the administration of normal salt solution, glucose, plasma or blood. Splints, plaster encasements or traction should be used when they are needed for supporting the diseased bone or to prevent contractures.

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## BLOOD IODINE STUDIES\*

### VII. THE RELATION OF THE BASAL METABOLIC RATE TO THE BLOOD IODINE IN THYROID DISEASE

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VARIOUS PATHOLOGIC PROCESSES, as well as changing physiologic states, produce deviations in the metabolism of the human body. These are reflected in the basal metabolic rate. Most important in this regard are the various diseases of the thyroid gland, an organ which plays an important, if not a dominant, rôle in setting the pace at which the body's myriad cells function. It is common clinical knowledge that the basal metabolic rate is decreased with diminution of thyroid activity, falling as low as minus 40 per cent in patients with total myxedema. Plummer and Boothby<sup>1</sup> found that the daily rate of thyroxine decay ranges between 0.2 and 0.4 mg. Thus, a therapeutic daily dose of from 0.3 to 0.4 mg. of thyroxine is necessary to maintain a normal basal metabolic rate in wholly myxedematous patients at bed rest.<sup>2</sup>

#### THE BASAL METABOLIC RATE IN THYROID DISEASE

The basal metabolic rate varies with the type of goiter. Boothby<sup>3</sup> found the average basal metabolic rate in 254 patients with nontoxic goiter to be plus 2 per cent. The distribution of basal metabolic rates in 1,111 patients with nodular goiter, without hyperthyroidism, was similar to that found in normal individuals.<sup>4</sup> On the other hand, the average basal metabolic rate was plus 30 per cent in 366 patients with toxic nodular goiter,<sup>3</sup> and exceeded plus 20 per cent in 93 per cent of 2,569 patients with exophthalmic goiter.<sup>4</sup> The average basal metabolic rates which we have obtained in similar but smaller groups agree well with those of Boothby (Table I). In all patients having goiter with hyperthyroidism, the rates are significantly elevated, along with the whole blood iodine. Although less increased, the basal metabolic rate in patients with nontoxic nodular goiter is nevertheless significantly higher than normal. In all goitrous conditions studied, as well as in thyroid malignancy, the variation in basal metabolic rates among patients exceeds that among normal persons.

In Table II is shown a comparison of the distribution of the basal metabolic rates in four different thyroid diseases with that in normal individuals. As in a similar study of the blood iodine distribution,<sup>6</sup> arbitrary limits are chosen on the basis of the standard deviation for normal persons. The distribution of values in the normal 1 s.d.\* and 2 s.d. limits varies considerably and thus accounts, at least in part, for the differences found in the

\* Aided by a grant from the Comly Fund for Research of the Ohio State University.

\* 1 s.d. = one times the standard deviation, etc.

average basal metabolic rate of each group. The deviation from normal is most marked in patients with hyperthyroidism (toxic nodular and exophthalmic goiter) in which almost 90 per cent of all values exceed the normal plus 2 s.d. limit, plus 11 per cent, and no values are below the minus 1 s.d. limit, minus 13 per cent.

TABLE I

AVERAGE BASAL METABOLIC RATE AND WHOLE BLOOD IODINE CONCENTRATION IN VARIOUS THYROID DISEASES

(+ - the Standard Error)

Clinical Condition	No.	Basal Metabolic Rate	No.	Blood Iodine†
		Mean + - Standard Error		(Micrograms %) Mean + - Standard Error
Hypothyroidism.....	77	-16±1*	66	3.6±0.1
Normal.....	46	- 5±1	39	4.2±0.2
Nontoxic diffuse colloid goiter.....	14	- 7±2	9	4.4±0.3
Nontoxic nodular goiter.....	72	+ 1±1†	44	3.9±0.2
Toxic diffuse colloid goiter.....	6	+26±9†	3	6.4±0.7†
Toxic mixed goiter.....	4	+26±5†	4	7.2±1.1†
Toxic nodular goiter.....	54	+28±2†	29	7.9±0.8†
Exophthalmic goiter.....	73	+39±3†	41	9.3±0.6†
Carcinoma of the thyroid.....	11	+16±5*	9	4.8±0.7
Chronic thyroiditis.....	3	-12±5	3	5.2±0.9

\* Significantly different from the normal average.

† Highly significantly different from the normal average.

‡ Chromium-trioxide method of blood iodine determination.<sup>5</sup>

TABLE II

PERCENTAGE DISTRIBUTION OF THE BASAL METABOLIC RATES IN THE NORMAL, 1 S.D. AND 2 S.D. LIMITS

(Normal Average Basal Metabolic Rate + - the Standard Deviation = -5±8%)

Percentage Distribution of Basal Metabolic Rates

Clinical Condition	No.	Range of Values (%)	Below -2 s.d.	-2 s.d. to -1 s.d.	-1 s.d. to Average	Average to +1 s.d.	+1 s.d. to +2 s.d.	Above +2 s.d.
			(Below -21%)	(-21 to -13%)	(-13 to -5%)	(-5 to +3%)	(+3 to +11%)	(Above +11%)
Hypothyroidism.....	77	-37 to +1	23%	46%	21%	10%	0%	0%
Normal.....	46	-19 to +21	0%	11%	39%	39%	4%	7%
Nontoxic nodular goiter.....	72	-23 to +35	1%	4%	26%	28%	20%	21%
Toxic nodular goiter..	54	-17 to +69	0%	1%	0%	6%	6%	87%
Exophthalmic goiter..	73	-9 to +100	0%	0%	1%	4%	8%	87%

An opposite tendency is found in hypothyroidism, with nearly 70 per cent of all basal metabolic rates below the 1 s.d. range and none above. In nontoxic nodular goiter the distribution shows a beginning shift toward higher values, with as many as 41 per cent of the basal metabolic rates above the plus 1 s.d. limit and half of these above the plus 2 s.d. limit. A comparison of the distribution of the basal metabolic rates with that of the whole blood in thyroid disease shows that *the basal metabolic rate alone more frequently indicates the presence of thyroid disease than does the unfractionated whole blood iodine* (Table III).

The similarity in distribution of basal metabolic rates within the described limits in toxic nodular goiter and in exophthalmic goiter is misleading without a consideration of the values exceeding the normal plus 2 s.d. limit. Such

values are higher in exophthalmic goiter than in toxic nodular goiter, attaining a maximum in the groups considered here of plus 100 per cent in exophthalmic goiter and of plus 67 per cent in toxic nodular goiter (Table II). This accounts for the significant difference in the average basal metabolic rates in exophthalmic goiter, plus 39 per cent, and in toxic nodular goiter, plus 28 per cent. A corresponding significant difference could not be demonstrated in

TABLE III

A COMPARISON OF THE DISTRIBUTION OF BASAL METABOLIC RATES AND WHOLE BLOOD IODINE VALUES IN THE NORMAL 1 S.D. AND 2 S.D. LIMITS

Clinical Condition	Below -2 s.d.	Within the 1 s.d. Limits	Within the 2 s.d. Limits	Above +2 s.d.
Hypothyroidism:				
Whole blood iodine.....	5%	70%	93%	2%
Basal metabolic rate.....	23%	31%	77%	0%
Normal:				
Whole blood iodine.....	0%	68%	97%	3%
Basal metabolic rate.....	0%	68%	93%	7%
Nontoxic nodular goiter:				
Whole blood iodine.....	1%	66%	92%	7%
Basal metabolic rate.....	1%	54%	78%	21%
Toxic nodular goiter:				
Whole blood iodine.....	0%	34%	55%	45%
Basal metabolic rate.....	0%	6%	13%	87%
Exophthalmic goiter:				
Whole blood iodine.....	0%	20%	37%	63%
Basal metabolic rate.....	0%	5%	13%	87%

the average unfractionated whole blood iodine values of these groups, 9.3 and 7.9 micrograms per cent, respectively<sup>6</sup> (Table I). More data, especially on *fractionated* blood iodine, might reveal a significant difference.

Werner<sup>7</sup> attributes the relatively lower basal metabolic rate found in nodular goiter to a slower and more gradual onset of the hyperthyroidism than in exophthalmic goiter. Whether this difference between the basal metabolic rates in these two forms of goiter with hyperthyroidism is actually due to a difference in the rapidity with which toxic symptoms become manifest or to other factors inherent in these diseases, we shall not discuss at this time. Our own studies also indicate that the onset of hyperthyroid symptoms is slower in nodular than in exophthalmic goiter. Hyperthyroid symptoms sufficiently severe to bring the patient to a physician took an average of 3.2 years to develop in our group of patients with toxic nodular goiter, and 1.4 years, or about half that time, in those with exophthalmic goiter.

In four patients with toxic mixed goiter and in six with toxic diffuse colloid goiter, the average basal metabolic rates are again lower than those found in exophthalmic goiter. Nevertheless, the average duration of hyperthyroid symptoms in the few with toxic mixed goiter approximates that in exophthalmic goiter, while the duration of these symptoms in those with toxic diffuse colloid goiter is equal to that in toxic nodular goiter. The average basal metabolic rate is plus 26 per cent both in toxic mixed and toxic diffuse colloid goiter, and agrees closely with the average basal metabolic rate in

toxic nodular goiter, in our series plus 28 per cent, as well as in Boothby's<sup>3</sup> series, plus 30 per cent (Table I).

The *average* basal metabolic rate in 72 patients with nontoxic nodular goiter, plus 1 per cent, is significantly greater than in a group of normal individuals from this region, minus 5 per cent, yet is far less than the average basal metabolic rate in toxic goiter. As many as 21 per cent of the basal metabolic rates in the group with nontoxic nodular goiter exceed the normal plus 2 s.d. limit, plus 11 per cent (Table II). A lower average metabolism is found in simple diffuse colloid goiter. The average is minus 7 per cent and does not differ significantly from the normal (Table I). However, the group is relatively small, comprising only nine patients, all young persons.

In carcinoma of the thyroid there are several factors involved which may exert their effects, singly or in combination, upon the body metabolism. If the carcinoma is locally extensive, one might even expect a much reduced basal metabolic rate because of massive destruction of thyroid tissue. In partial replacement of the normal gland, on the other hand, there may be compensatory overfunctioning of the remaining cells, in varying degrees. In addition to these factors, the type of thyroid abnormality present prior to the development of the carcinoma may also be reflected in the basal metabolic rate. We have postulated in a previous paper<sup>6</sup> that the level of the blood iodine may depend more upon the nature of the thyroid gland in which the malignancy arises than upon the character of the malignancy itself. However, this again would be influenced, as in the case of the basal metabolic rate, by the extent of destruction of functioning thyroid tissue and the degree of resultant overcompensation by the remaining normal cells.

In carcinoma of the thyroid we have, in addition to the thyroid activity present, another factor which may be reflected in the basal metabolic rate. This is the process of malignancy itself. Unlike the level of the blood iodine,<sup>8</sup> the basal metabolic rate is in general increased by malignant neoplastic disease.<sup>4, 9</sup> Thus, moderate elevation of the average basal metabolic rate in 11 patients with carcinoma of the thyroid, plus 16 per cent, may be consistent with the degree of increase one might expect to find in most malignant disease. As can be gleaned from the work of Boothby and Sandiford,<sup>4</sup> the percentage of basal metabolic rates exceeding plus 20 per cent is almost the same in malignancy of the thyroid as in certain other malignant neoplastic disease, the values being plus 22 and 20 per cent, respectively.

#### BASAL METABOLIC RATE AND WHOLE BLOOD IODINE IN THYROID DISEASE

Unlike thyroid disease, other endocrine disturbances are not so consistently reflected in the basal metabolic rate. Findings of the basal metabolic rates in these nonthyroid diseases<sup>9, 10</sup> suggest that the values frequently do not parallel the *hypo* and *hyper* states of the glands involved.<sup>10</sup> Moreover, thyroid disease differs from nonthyroid disease in the corresponding general changes observed in the basal metabolic rate and the level of the blood iodine, particularly of the various forms of "organic iodine."<sup>12-14</sup>

It appears to be the increased protein-bound fraction of the blood iodine, and more particularly its thyroxine-containing portion, which is related to the increased basal metabolic rate of hyperthyroidism.<sup>15, 16</sup> In a series of 100 patients with suspected thyroid disturbances and of ten control individuals, Salter, and his associates,<sup>11</sup> found that when the clinical diagnosis and basal metabolic rate are in agreement, there is close parallelism between the plasma protein-bound iodine and the basal metabolic rate. Of 29 per cent who did not show such a relationship, the plasma protein-bound iodine proved more reliable as an index of the clinical status than did the basal metabolic rate, particularly in "Graves' disease without hyperthyroidism."

Further, the similar response of both the basal metabolic rate and the blood iodine to thyroid therapy suggests again an association of these factors. Thus, for example, in the treatment of myxedema with thyroxine,<sup>17</sup> or with thyroid gland,<sup>13</sup> the basal metabolic rate and the protein-bound blood iodine rise, while in hyperthyroidism treated with inorganic iodine, the "organic" level of blood iodine usually declines with the basal metabolic rate.<sup>18</sup> The recent investigations of thiouracil therapy in hyperthyroidism reveal that with this drug, too, the drop in basal metabolic rate, as well as the alleviation of symptoms,<sup>19, 20</sup> is accompanied by a drop in the protein-bound iodine of the blood.<sup>20</sup>

In a study of 18 children, from two to 13 years of age, Macciotta found no constant relation between the blood iodine and the basal metabolic rate, either in the group as a whole or in the same individual. From these findings he concludes that other factors besides the thyroid must be important in the iodine metabolism of children.<sup>21</sup> K. B. Turner, and his associates,<sup>22</sup> could find no correlation between the total blood iodine and the basal metabolic rate in 20 patients with hyperthyroidism, in five with nontoxic nodular goiter and in two with thyroiditis, as well as in patients with hypertensive vascular disease or with leukemia.

In 1935, Mobius and Nolte<sup>23</sup> observed a sharp parallelism between the increased basal metabolic rate and the per cent rise in blood iodine in untreated hyperthyroidism. In 1938, Gerda Bülmann<sup>13</sup> noted that the graphic relationship between the alcohol fractionated "protein-bound" iodine in Graves' disease and the basal metabolic rates, ranging from plus 80 to plus 180 per cent, resembled a logarithmic curve. Empirically, through various combinations of the data, she found the best equation describing the relationship to be: Per cent B.M.R. — 29 = 100 log (micrograms per cent iodine). From her findings she concluded that a relatively greater amount of circulating thyroid hormone is required to maintain a high metabolism; also, that a departure from a normal basal metabolic rate does not occur without change in the "protein-bound" iodine.

Salter<sup>24</sup> was able to demonstrate a highly significant correlation between the blood iodine and the basal metabolic rate, on data for which Elmer and Scheps<sup>25</sup> could find no parallelism, by using a logarithmic relationship:

$B.M.R. = \log (\text{blood iodine} - 3)$ , in which 3 is an arbitrary constant roughly representing the amount of inorganic iodine in the blood. His data included small groups of hyperthyroid patients, euthyroid normal individuals, euthyroid goiter patients, euthyroid individuals with low basal metabolic rates and hypothyroid patients. Salter<sup>24</sup> states that it can be inferred that the blood iodine and the basal metabolic rate are related: if the clinical classification is adequate; the analytical technic good; the exogenous iodine intake low; and a steady physiologic state is attained before the blood is drawn for analysis.

In a study of 373 mixed cases, with basal metabolic rates ranging from minus 30 to plus 50 per cent, McClendon and Foster<sup>14</sup> found a significant linear correlation between the basal metabolic rate, denoted in calories per sq. m. per hr., and the "thyroxin" iodine, a fraction which is nonextractable with methyl alcohol followed by acetone. The correlation coefficient thus obtained was  $+0.627$ .

In considering the total blood iodine, the basal metabolic rate and other factors in a series of different physiologic and pathologic conditions, we have found that the average unfractionated blood iodine is not invariably elevated in those conditions in which the basal metabolic rate is elevated.<sup>6, 8, 9</sup> Likewise, the average basal metabolic rate does not necessarily correspond to an increase in the level of the blood iodine. In all forms of toxic goiter, both are abnormally high (Table I). On the other hand, the moderate elevation in average basal metabolic rate which may occur in nontoxic nodular goiter is not accompanied by a corresponding increase in the blood iodine (Tables I and III). Likewise, a parallelism between increased metabolism and level of the blood iodine may be absent in carcinoma of the thyroid (Table I). In hypothyroidism the basal metabolic rate may be reduced out of proportion to the level of the average unfractionated blood iodine, perhaps due to a history of iodine medication in such patients or to the inclusion of patients with other hypometabolic disturbances in this group (Tables I and III).

In an analysis of covariance, including a total of 11 euthyroid (151 individuals) and eight different thyroid conditions (200 patients), we could not demonstrate a single relationship between the whole blood iodine and the basal metabolic rate which would similarly describe all. Significant correlations between the unfractionated blood iodine and the basal metabolic rate were found only in disease of thyroid origin. These included nontoxic nodular goiter, toxic nodular goiter and exophthalmic goiter, all groups in which there was a relatively large number of individuals (Tables IV and V). The association between the blood iodine and the basal metabolic rate in these three diseases was further corroborated by significant multiple correlation coefficients indicating some probable relationship of the blood iodine with the basal metabolic rate to the duration of symptoms of the disease, as well as to the age of the patient (Table V).

We<sup>5</sup> could demonstrate a significant correlation between the basal metabolic rate and the unfractionated blood iodine in 64 patients with hypothyroidism,



whose whole blood iodine was determined by the chromium trioxide method. This may be due to the same factors responsible for a normal average blood iodine in this group,<sup>6</sup> such as the inclusion of patients who may have received iodine medication, or of those with forms of hypometabolism other than actual hypothyroidism. A heterogeneity among the patients with hypothyroidism is further suggested by the finding of significant correlations between

TABLE IV  
CORRELATION COEFFICIENTS OF BASAL METABOLIC RATE AND WHOLE BLOOD IODINE  
IN 19 DIFFERENT CLINICAL CONDITIONS

Clinical Condition	Number of Individuals	Correlation Coefficient
Euthyroid:		
Normal.....	34	+0.153
Functional disturbances.....	25	-0.336
Psychoneurosis.....	17	+0.237
Obesity.....	15	-0.207
Menopause.....	12	+0.284
Hypertension.....	12	+0.115
Arthritis.....	10	+0.108
Hypometabolism.....	9	+0.141
Migraine.....	9	-0.209
Hirsutism.....	5	-0.338
Diabetes mellitus.....	3	-0.388
Thyroid:		
Hypothyroidism.....	64	+0.148
Nontoxic diffuse colloid goiter.....	7	+0.240
Nontoxic nodular goiter.....	44	+0.376*
Toxic diffuse colloid goiter.....	3	+0.254
Toxic mixed goiter.....	4	+0.823
Toxic nodular goiter.....	29	+0.548†
Exophthalmic goiter.....	40	+0.444†
Carcinoma of the thyroid.....	9	-0.151
* Significant correlation.		
† Highly significant correlation.		

TABLE V  
SIGNIFICANT CORRELATION COEFFICIENTS. RELATIONSHIP OF WHOLE BLOOD IODINE,  
BASAL METABOLIC RATE, DURATION OF SYMPTOMS AND AGE OF PATIENT

Thyroid Disease	Correlation Coefficient of Blood Iodine, B.M.R.		Multiple Correlation Coefficient of Blood Iodine, B.M.R.	
	Linear Relation	Logarithmic Relation	Duration of Symptoms	Age of Patient
Toxic nodular goiter.....	+0.548†	+0.563†	+0.569†	+0.555†
Exophthalmic goiter.....	+0.444†	+0.454†	+0.450†	+0.449†
Nontoxic nodular goiter.....	+0.376*	+0.330*	+0.396*	+0.427*
Hypothyroidism‡:				
6 males.....	+0.833*	+0.868*	.....	.....
7 females.....	.....	.....	.....	+0.986†
* Significant correlation.				
† Highly significant correlation.				
‡ Explained in text.				

the basal metabolic rate and the whole blood iodine only when males and females were considered separately in another smaller group of hypothyroid patients (Table V), whose blood iodine was determined by the dry ash technic.<sup>26</sup>

Further correlation between the basal metabolic rate and the blood iodine

should be expected since a part, at least, of the blood iodine appears to represent the circulating thyroid hormone. Also, significant correlation coefficients might be found in other clinical conditions, besides those in which we were able to demonstrate them, when the "organic" fraction of the blood iodine is contrasted with the basal metabolic rate, especially in larger groups of individuals.

In our analysis of covariance we were unable to find any significant departure of the whole blood iodine-basal metabolic rate relationship from linearity in those diseases in which a significant correlation between these two factors was found. Moreover, using the logarithmic relationship, with or without constants, we found that the correlation coefficients thus obtained in each of the 19 conditions (11 euthyroid and eight thyroid) investigated did not differ significantly from those obtained on a linear basis. Likewise, the logarithmic equation did not better describe a single relationship between the blood iodine and basal metabolic rate which would hold for all 19 considered as a whole.

#### SUMMARY

1. In all forms of toxic goiter, the average basal metabolic rate is elevated. However, it is more increased in exophthalmic goiter than in any other form of goiter with hyperthyroidism, despite a similarity in the extent of increase of the average unfractionated whole blood iodine in all forms of toxic goiter, with or without exophthalmos.

2. Although lower than the average basal metabolic rate found in toxic goiter, those of 72 patients with nontoxic nodular goiter were significantly higher than normal. This moderate increase in the average was unaccompanied by any average increase in the whole blood iodine.

3. The moderate elevation of the average basal metabolic rate in 11 patients with carcinoma of the thyroid may be consistent with the degree of increase one might expect to find in most malignant disease. On the other hand, it may be the result of various factors including the nature of the thyroid gland in which the carcinoma develops, the extent of destruction of functioning thyroid tissue and the degree of resultant compensation by the remaining cells, as well as the presence of malignancy *per se*.

4. Variation in the basal metabolic rates in different goitrous conditions was found to exceed such variation among normal individuals.

5. Significant positive correlation coefficients indicating a probable association between the basal metabolic rate and the whole blood iodine were demonstrated in nontoxic nodular, toxic nodular and in exophthalmic goiter. There was no significant deviation from linearity in any of these relationships.

6. An interrelationship between the whole blood iodine and basal metabolic rate with the duration of symptoms of the disease, as well as with the age of the patients, was indicated in all three of these diseases by significant multiple correlation coefficients.

7. The determination of the basal metabolic rate is a more reliable test

of thyroid activity than the level of the unfractionated whole blood iodine. However, both determinations, considered together, are superior to either alone.

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# VAGOTOMY FOR GASTRODUODENAL ULCER\*

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A VOLUME to honor the 20 years of superb service that Dr. Dallas B. Phemister has given to the Department of Surgery and to the Medical School of the University of Chicago is fitting and appropriate. It is a great pleasure and a privilege for me to take part in this celebration, for I have been closely associated with him during all this time. We have worked together and what I have learned of surgery has come chiefly from him. He has taught best by example, and his modesty and industry, but best, his scientific integrity have set the standard, and this is chiefly responsible for the accomplishments of the Department. Sustained experimentation in the laboratory and honest observation and recording in the Clinic have constantly marked his way. Few men have done so well in both fields. Enthusiasm goes with him and the will to work. It is especially gratifying that this occasion looks upon him in the full flood of his powers and we hope that it will convey, even though faintly, our warm admiration and regard.

In previous papers<sup>1</sup> I have presented our early experience with surgical division of the vagus nerves in patients with gastroduodenal ulcer, together with brief descriptions of the operative technic involved. It is the purpose of this communication to survey the present status of this work and to refer to some studies in the laboratory that provide for the first time information concerning the relative importance of nervous and humoral factors in determining the volume and acidity of the gastric secretion.

The operation was undertaken because of the conviction, arrived at by experimental work on the lower animals, that pure gastric juice as it is secreted by the fundus of the stomach, has the capacity to destroy and digest various living tissues, including the wall of the jejunum, duodenum, and even the stomach itself.<sup>2</sup> It does not do this under normal conditions because the usual and appropriate stimulus to gastric secretion is the ingestion of food. This dilutes and neutralizes the gastric juice and decreases its corrosive powers. In normal man the secretion of gastric juice in the intervals between meals, when there is no food in the stomach or upper intestines, falls off to a small quantity that can be buffered by the saliva, pyloric mucus, and the regurgitated duodenal secretions. The chief secretory abnormality in ulcer patients lies not in the production of a juice with higher than normal acidity, nor even in the production of more normal juice in response to the usual stimuli, although there is some evidence that this occurs, but rather in the secretion of abnormally large amounts of gastric juice in the intervals between meals particularly at night when the stomach is empty and there is no obvious

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\* This work was done with the aid of a number of associates, including F. M. Owens, Jr., M.D., P. W. Schafer, M.D., T. F. Thornton, Jr., M.D., E. H. Storer, M.D., and James Clarke, M.D.

stimulant. The accumulation in the stomach of considerable amounts of such relatively pure fundic secretion obviously provides in man the counterpart of those experiments in animals where ulcers inevitably develop and become progressive.

The medical management of duodenal ulcer has been successful directly dependent upon the degree to which the acid gastric juice has been neutralized during the entire 24 hours. Surgical treatment, likewise, has been successful when a sufficient part of the fundus mucosa has been removed to reduce the

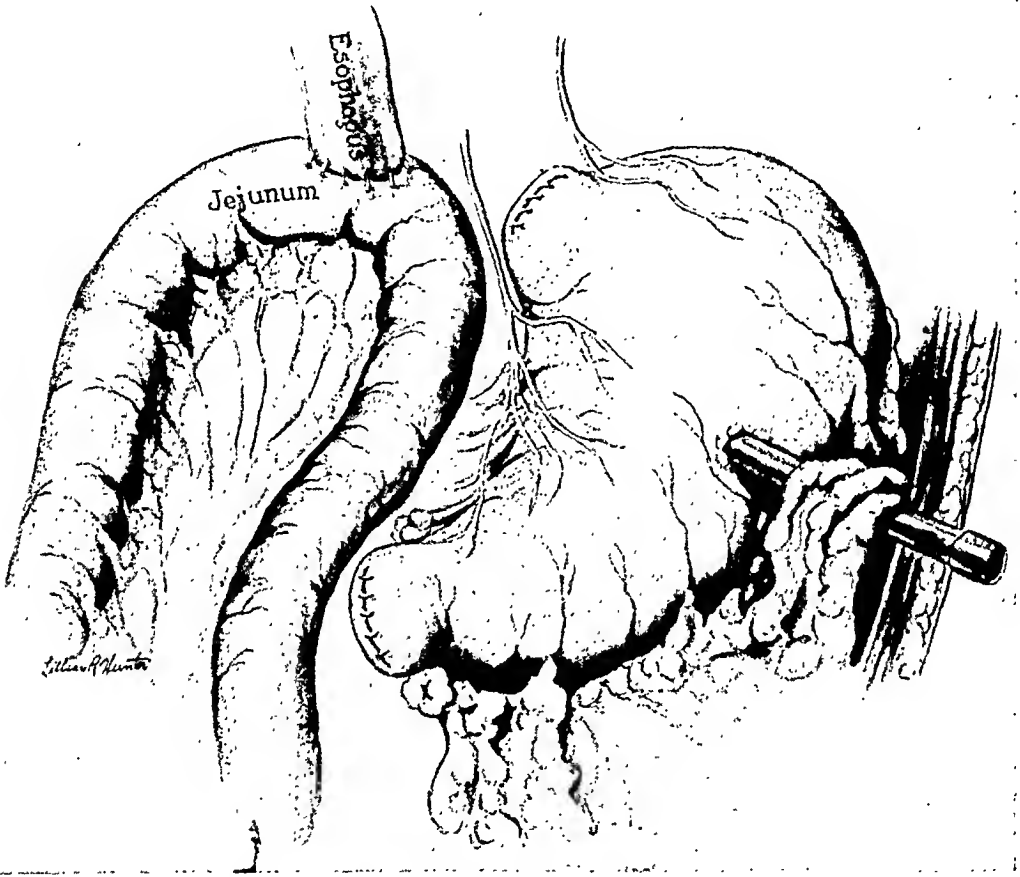


FIG. 1.—Diagram illustrating the totally isolated stomach preparation with preservation of the vagus innervation and blood supply.

gastric secretion to normal or subnormal values. The importance of the vagus nerves in the normal mechanism of gastric secretion has been recognized since the classical researches of Pavlov, and his pupils. However, it is possible that the discovery of humoral factors also effecting gastric secretion, notably gastrin and histamine, has directed the attention of many students to this phase of gastric physiology and has led to the employment of humoral stimuli exclusively in testing gastric secretory function in health and disease. Reliable data on the total volume of gastric juice secreted by normal man in 24 hours are very meager. There seems to be no way to apply the usual normal stimuli to the gastric glands and still recover the secretory product.

There is also little or no information concerning the relative proportion of gastric juice that is elicited by neurogenic stimuli and by humoral factors.

Some data bearing on this problem have been recently obtained in our laboratory, the details of which will be reported elsewhere. In this work, total isolated stomach pouches were prepared in dogs by the method of Dragstedt and Ellis.<sup>3</sup> The lower end of the esophagus was mobilized and the vagus nerves carefully pushed aside. The esophagus was then transected and the upper end of the stomach infolded and closed. The pylorus was then



FIG. 2.—Incision (A) and exposure (B) of the 7th rib for transthoracic vagotomy.

transected, both ends infolded and closed, and the jejunum brought up and anastomosed to the esophagus by end-to-side suture. A gold plated cannula was inserted into the isolated stomach for the collection of gastric juice (Fig. 1). In a typical experiment such an isolated stomach, in which the blood supply and the vagus innervation had been carefully preserved, was found to secrete an average of 1,100 cc. of gastric juice with a free hydrochloric acid concentration of 0.35 to 0.42 per cent in 24 hours. The total secretion for a month was collected and then the vagus nerves were divided in the chest just above the diaphragm. The volume of gastric juice immediately declined to an average of 410 cc. with a free acidity of 0.11 to 0.32 per cent, and this effect persisted for at least 60 days.

By this type of experiment it was found that section of the vagus nerves to the stomach reduced the secretion of gastric juice in dogs to a half or even a fourth of the normal level. Unless it should develop that psychic factors are more important in gastric secretion in dogs than in man, it appears highly

probable that a similar reduction can be expected. The data obtained so far, suggest that the hypersecretion of gastric juice in ulcer patients is neurogenic in origin and that, consequently, a comparatively greater reduction should follow vagus section in man than in lower animals.

At the present time, 39 patients have been treated by vagus section in this Clinic. In 32 of these, the vagi have been divided in the left chest just above the diaphragm. The technic of this operation is illustrated in Figures 2, 3, and 4. An extensive resection of the seventh or eighth rib together with a portion of the cartilage is made so that retraction of the wound will produce minimum trauma. The intercostal nerve is isolated at the posterior margin of the wound, divided and ligated with silk. This procedure minimizes post-

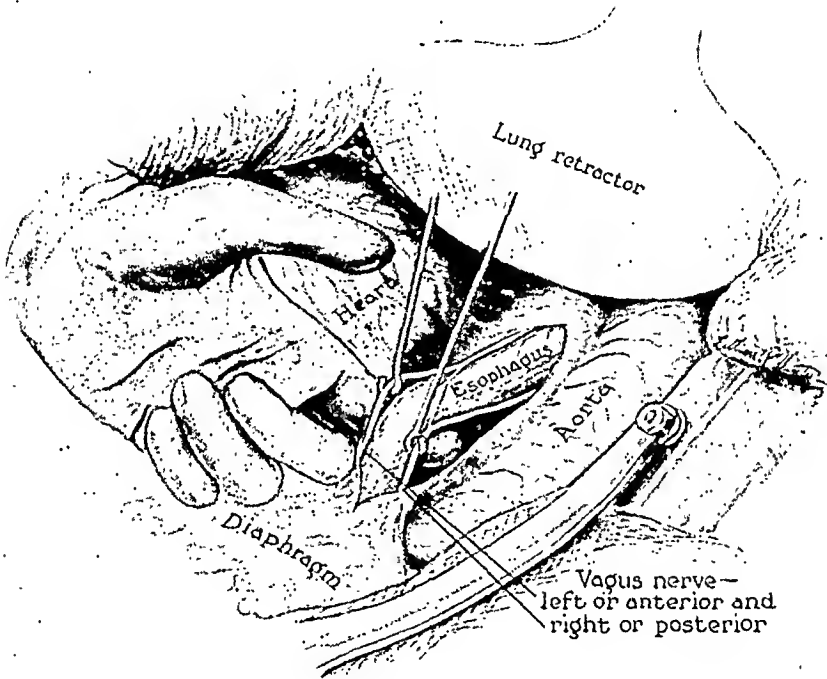


FIG. 3.—Mobilization of the esophagus and isolation of vagus nerves showing the communication between the anterior and posterior trunks.

operative pain in the chest, otherwise a troublesome complication. The inferior pulmonary ligament is clamped, cut, and ligated and the incision in the parietal pleura carried backward toward the aorta about 2 cm. The finger is then introduced through this aperture and the esophagus mobilized into the left chest by gentle blunt dissection. The vagus nerves may be easily identified by palpation, ligated with silk and divided as in Figure 3. The proximal ends of the divided nerves are sutured into the left pleural cavity to hinder regeneration. The chest is closed without drainage.

In seven of the patients, the vagus nerves have been divided below the diaphragm, usually because an associated high grade pyloric stenosis necessitated a gastro-enterostomy or resection to relieve obstruction. The method



employed is illustrated in Figures 5, 6 and 7. An inverted T-shaped incision (Fig. 5A) provides good access to the lower esophagus. The left triangular ligament of the liver is incised and the left lobe of the liver retracted medially (Figs. 5B and C). The peritoneal fold over the esophagus is severed and the esophagus mobilized by blunt dissection and pulled downward into the abdomen. Often 5 cm. or more of esophagus may be delivered into the abdomen by this method. The left, or anterior vagus nerve is found along the lesser curvature usually in the form of several separate strands which

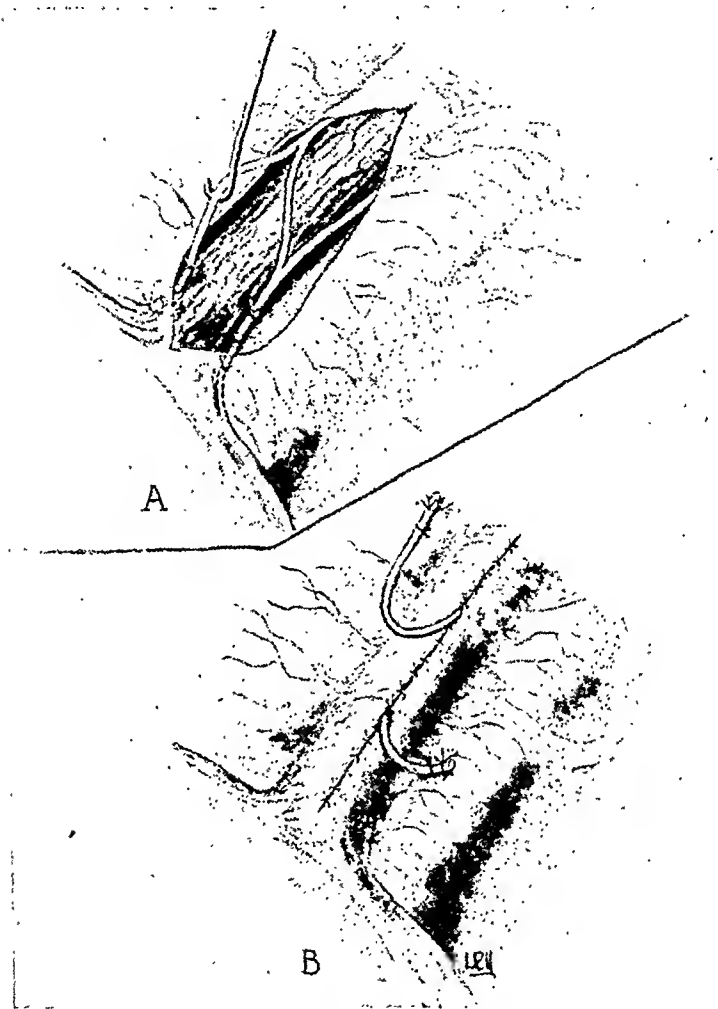


FIG. 4.—(A) Ligature and division of vagus nerves just above diaphragm; and (B) transplantation of proximal ends of cut vagi into the pleural cavity.

can be grouped together. The right, or posterior vagus is found along the greater curvature. It is most important to clear the esophagus of all nerve fibers for a distance of 2 or 3 cm. and to divide all the fibers passing to the stomach through the diaphragm. It is somewhat more difficult to secure a complete vagotomy by this abdominal approach but it can be accomplished if sufficient care is exercised. The nerve trunks are cut between silk ligatures and the proximal ends permitted to retract into the mediastinum, or they may be sutured to the diaphragm as in Figure 7.

The insulin test, as suggested by Hollander,<sup>4</sup> has been employed in our

TABLE I  
TABULATED SUMMARY OF DATA ON PATIENTS UPON WHOM SECTION OF THE VAGUS NERVES WAS PERFORMED FOR GASTRODUODENAL ULCER

Patient	Unit No.	Age and Sex	Duration of Symptoms Years	Diagnosis	Direct Visualization of Ulcer with Gastro-scope	Roentgen-ray Evidence of Ulcer Crater	Pyloric Stenosis	Hemorrhage	Perforation	Postop. Free Acid	Date of Vagus-Section	Remarks
H. F.	344351	54 ♂	20	Duodenal ulcer	-	+	+++	++	+	35	10-25-44	Subdiaphragmatic vagotomy plus gastro-enterostomy. Complete relief. No recurrence to 5-10-1945
H. W.	329519	55 ♂	20	Duodenal ulcer	-	+	+++	++	-	0	11-10-44	Subdiaphragmatic vagotomy plus gastro-enterostomy. Complete relief. No recurrence to June, 1945
C. B.	345581	42 ♂	26	Gastro-enterostomy 1928 Gastrocolic fistula 1930 Partial gastrectomy 1938	-	+	-	+	+	0	11-18-44	Supradiaphragmatic vagotomy. Slight relief. Total gastrectomy July, 1945
M. B.	285298	56 ♂	12	Gastrojejunal ulcer Gastro-enterostomy 1942 Gastrojejunal ulcer	-	+	-	++	-	36	11-24-44	Gastro - enterostomy taken down. Supradiaphragmatic vagotomy. Complete relief. No recurrence to June, 1945
J. W.	293108	60 ♂	25	Gastro-enterostomy 1936 Gastrojejunal ulcer	+	+	-	-	-	0	11-27-44	Supradiaphragmatic vagotomy. Pain in incision, ulcer palm relieved. No recurrence to July, 1945
A. W.	346494	47 ♂	15	Gastro-enterostomy 1942 Gastrojejunal ulcer	-	+	-	++	0	0	12-11-44	Supradiaphragmatic vagotomy. Complete relief, with no recurrence to Feb. 1945
H. K.	345881	38 ♂	20	Duodenal ulcer	-	+	+	-	-	24	12-27-44	Supradiaphragmatic vagotomy. Complete relief. No recurrence to 5-6-45
H. M.	325181	30 ♂	7	Duodenal ulcer	-	+	+	+	-	6	12-29-44	Supradiaphragmatic vagotomy. Complete relief. No recurrence to May, 1945
N. K.	330562	48 ♂	7	Duodenal ulcer	-	+	+	+	-	19	1-3-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to April, 1945
M. C.	57621	54 ♂	20	Duodenal ulcer	-	+	-	-	-	-	1-5-45	Supradiaphragmatic vagotomy. Death from pneumonia

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E. T.	347888	60 ♀	15	Duodenal ulcer	-	+	+	+	-	-	786	358	44	0	1-8-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to July 1945
R. V.	343287	42 ♂	1	Duodenal ulcer	-	-	+	-	-	-	1043	486	82	61	1-10-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to April, 1945.
W.H.S.	345905	52 ♂	26	Duodenal ulcer	-	+	+	+	+	-	1165	893	35	25	1-19-45	Subdiaphragmatic vagotomy plus gastro-enterostomy. Complete relief. No recurrence to April, 1945
J. P.	349287	54 ♂	8	Duodenal ulcer	-	-	+	+	+	-	405	571	23	14	1-19-45	Subdiaphragmatic vagotomy plus gastro-enterostomy. Complete relief. No recurrence to April, 1945
W. W.	351791	57 ♂	2	Duodenal ulcer	-	-	+	+	-	+	756	523	54	15	2-23-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to July, 1945
G. P.	328604	48 ♂	20	Subtotal gastrectomy 4-3-44.	-	+	-	-	-	-	1126	233	12	0	3-12-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to July, 1945
M. S.	204878	42 ♂	6	Gastrojejunal ulcer	-	+	-	-	+	-	310	395	6	0	3-23-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to June, 1945
G. K.	76605	43 ♂	4	Subtotal gastrectomy 1943.	-	+	-	-	-	-	460	248	31	14	3-21-45	Supradiaphragmatic vagotomy. Roentgen-rays show marked decrease in ulcer crater in 6 weeks
W. K.	355373	52 ♂	15	Gastrojejunal ulcer	+	+	+	-	-	-	1086	295	46	11	4-13-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to July 1945,
C. W. O.	4977	42 ♂	16	Gastric ulcer	-	-	+	+	-	-	642	212	66	2	4-18-45	Supradiaphragmatic vagotomy. Complete relief. No recurrence to July, 1945
J. A.	333605	44 ♂	15	Duodenal ulcer	-	+	+	+	+	-	627	347	35	0	5-20-45	Subtotal gastrectomy, plus subdiaphragmatic vagotomy. Complete relief. No recurrence to August, 1945
G. H.	270528	47 ♂	15	Duodenal ulcer	-	+	+	+	-	-	1838	630	19	0	6-20-45	Subdiaphragmatic vagotomy plus gastro-enterostomy. Complete relief. No recurrence to August, 1945
J. G.	359155	31 ♀	15	Duodenal ulcer	-	+	+	-	-	-	881	238	43	17	7-2-45	Subdiaphragmatic vagotomy.
T. M.	358801			Duodenal ulcer	-	+	-	+	+	-	1138	494	78	25	7-23-45	Supradiaphragmatic vagotomy.

work to determine if all the vagus secretory fibers to the stomach have been interrupted. This test depends upon the fact that the hypoglycemia induced by an adequate dose of insulin stimulates the vagus secretory fibers to the stomach probably by an effect on the central nervous system. As a rule, the injection of 20 units of insulin in a normal adult produces a fall in the blood

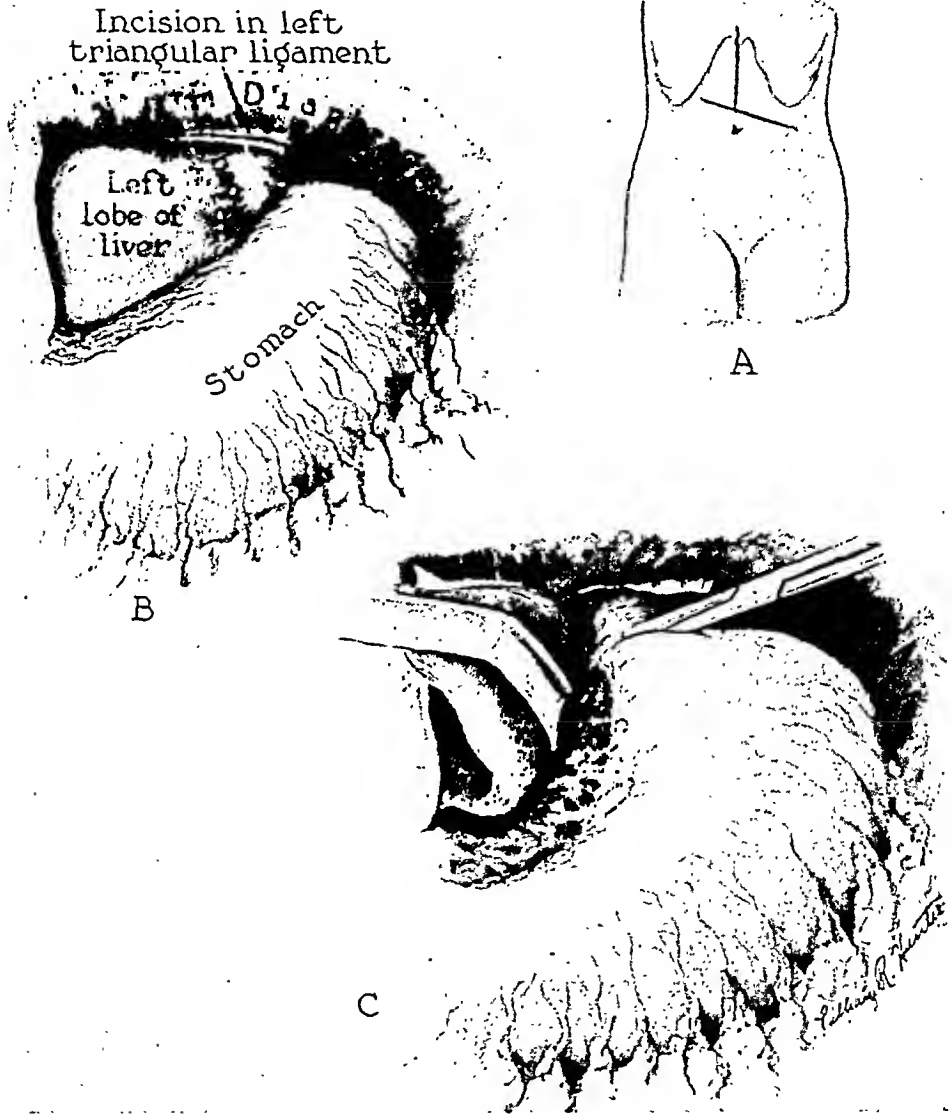


FIG. 5.—(A) Incision for transabdominal vagotomy. (B) Division of the left triangular ligament to the liver. (C) Exposure of esophagus.

sugar to 40 mg. or lower, and in about 30 minutes to an hour a marked augmentation in the rate and acidity of the fasting secretion results. No effect whatever occurs if the vagus section has been complete. The test must be controlled by estimations of the blood sugar before and one hour after the injection of insulin. The sugar must fall to 50 mg. or lower or no stimulation of the vagi is produced. In the last 21 patients, a positive response to the injection of insulin was obtained in 19 before operation, and this was

completely absent after the vagus section, except in one case where a doubtful positive response occurred in one test. -

The data concerning the first 15 patients subjected to vagus section have been summarized in a previous report.<sup>1</sup> A tabulated summary of the remaining 24 is included here, Table I. Brief protocols of relevant data in the histories of these patients are also presented.

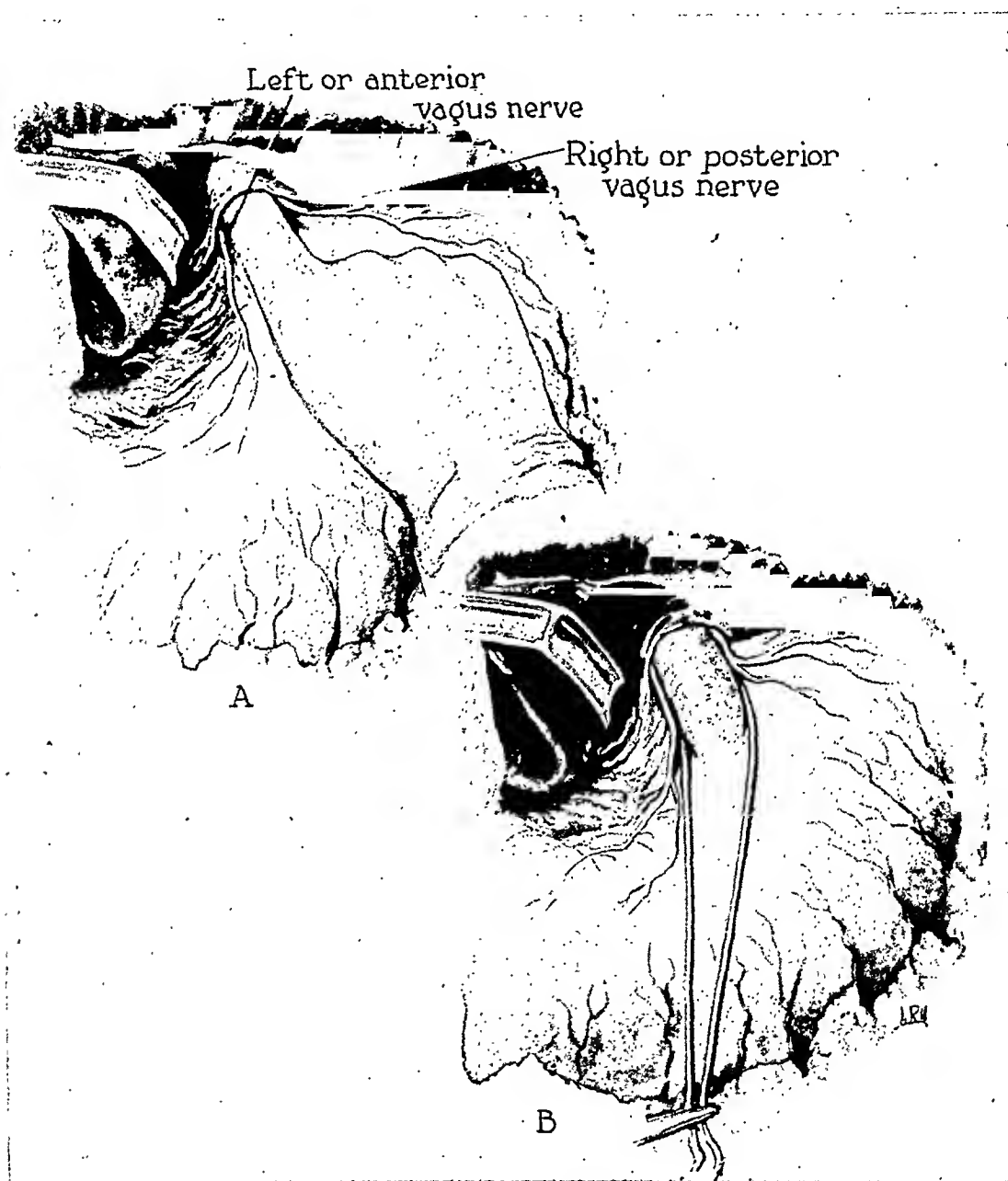


FIG. 6.—(A and B) Mobilization of esophagus.

It will be noted that one of the 39 patients died, a mortality for the operation at present of 2.5 per cent. This patient developed a postoperative bronchopneumonia due, in part to the aspiration of regurgitated material which had accumulated in the stomach. It is now our practice to maintain constant intragastric suction for three to four days after operation or until

the stomach has recovered sufficient tonus to prevent the accumulation of more than 200 cc. of fluid. There have been no other serious postoperative complications. As noted before, pain along the rib margin was a troublesome development in many of the early cases. This has been very largely prevented by the division of the intercostal nerve at the posterior margin of



FIG. 7.—Isolation and division of vagus trunks.

the wound. It is probable that a pleural effusion of varying amount occurs in all patients, but this has required aspiration in only 25 per cent. A second aspiration was performed three times. There is undoubtedly a hazard from atelectasis and bronchopneumonia. The practice of early rising has probably lessened the incidence of these complications. Almost all of the patients get out of bed after 24 hours and remain so for long periods on the third or fourth day.<sup>5</sup>

## VAGOTOMY FOR GASTRODUODENAL ULCER

Thirty of the patients subjected to vagus section had duodenal ulcers, two had gastric ulcers and seven had gastrojejunal ulcers. Eight of the duodenal ulcer patients were given a gastro-enterostomy in addition to the vagus section because of high grade pyloric stenosis. In five of these the gastro-section was done by the abdominal approach at the same time as the vagus enterostomy. Only one of the duodenal ulcer patients failed to obtain striking and persistent relief of symptoms, and in this case there were many features suggesting a neurosis. The first patients have been followed for two and one-half years and, so far, have remained well on unrestricted diets and without medication. One of the patients with gastric ulcer has been entirely cured of his disease as determined by gastroscopic and roentgenographic evidence and complete relief of symptoms. The other has been relieved of distress and at the last examination a marked reduction in the size of the ulcer crater was apparent. These ulcers are notoriously difficult to heal without resection. Of the seven patients with this lesion, one was dissatisfied with the result and went to another clinic where a total gastrectomy was performed. One patient secured complete relief of distress only with additional alkalis, but was able to return to work as a sailor and has not been seen during the past year. The remaining five have secured complete relief of ulcer distress, and in three of these, a spectacular recession in the craters, visualized roentgenographically, has been obtained. A longer period of observation is required before conclusions can be drawn in this group.

Studies on the effect of vagus section on gastric secretion and motility in ulcer patients have been made, and will be reported in detail elsewhere. The operation has no effect on the secretory response of the stomach to histamine or caffeine but abolishes the stimulating effect of insulin hypoglycemia and a sham meal. Confirming our earlier experience, the most definite and consistent secretory abnormality in ulcer patients is an abnormally large continuous secretion of gastric juice in the empty stomach at night when there is no apparent stimulus. This occurred without exception. Vagotomy reduced this secretion from 50 to 60 per cent, indicating that it is largely neurogenic in origin. The tonus and hunger contractions of the stomach in patients with duodenal ulcer are usually excessive and are reduced but not abolished by vagotomy. A temporary atony of the fundic region was observed in two patients by fluoroscopy. It is very likely that this reduction in hypertonicity in part accounts for the immediate symptomatic relief so commonly produced. Although a decrease in the motility of the stomach was found in each case when the examination was made, no evidence has been obtained, so far, indicating a similar decrease in the motility of the intestines. If any effect at all has been produced, it is in the direction of increased peristalsis. A considerable proportion of the patients who complained of constipation before the operation have been even more gratified by the disappearance of this disturbance than by the relief of the ulcer distress. Further study of this effect is necessary.

## CLINICAL PROTOCOLS

H. F. (Unit No. 344351), a 54-year-old white male, was first seen in this clinic on October 18, 1944. He gave a history of epigastric distress for the previous 20 years, during which time he secured partial relief by food and alkalis. Eight years ago he had an attack of nausea and vomiting and a profuse gastric hemorrhage. Shortly after this attack he was operated upon for a perforated duodenal ulcer. After recovery from the operation he followed an ulcer management with frequent feeding and powders faithfully. When he came to this clinic his abdominal pain had become more severe, vomiting was frequent and he had passed tarry stools for the preceding two days. Roentgenologic examination revealed a duodenal ulcer with a crater and high grade pyloric obstruction. On October 25, 1944, a celiotomy was performed and a stenosing duodenal ulcer demonstrated. The lower esophagus was mobilized, the vagus nerves ligated and divided, and a posterior gastro-enterostomy made. Recovery from the operation was uneventful, and the patient has had no epigastric distress of any kind subsequently. When last seen in May, 1945, he was eating a regular diet, without medication, and had no distress.

C. B. (Unit No. 345581), a 42-year-old white male, was first admitted to the clinic on November 7, 1944. He complained of epigastric distress occurring several hours after meals and at night ever since he was 16 years old. The ingestion of food or milk always relieved the pain. In 1928, a posterior gastro-enterostomy was done for duodenal ulcer. Following this operation his abdominal pain persisted and he developed diarrhea. He was operated upon again in 1930, at which time a gastrojejunal fistula was found. This was closed and the gastro-enterostomy taken down. The epigastric pain persisted and, in 1938, a subtotal gastrectomy was performed. This provided temporary relief, but early in 1944 symptoms recurred, and roentgenologic examination revealed a gastrojejunal ulcer. Medical management provided only partial and temporary relief and he began to vomit. Roentgenologic examination in this clinic on November 14, 1944, revealed a large jejunal ulcer. On November 18, 1944, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery was uneventful. On February 28, 1945, roentgenologic examination revealed a decrease in the size of the ulcer crater. The epigastric distress improved and he began to eat very well, but was severely injured in an automobile accident in 1945. He recovered from this accident but his epigastric distress recurred and he entered another clinic where a total gastrectomy was performed.

H. W. (Unit No. 329517), a 55-year-old white male, was first seen in this clinic on March 14, 1944. For the preceding 20 years he had been having epigastric pain after meals and at night. No adequate therapy was given during this period. On two occasions in 1943 he had massive gastro-intestinal hemorrhages. On June 24, 1944, roentgenologic examination revealed a duodenal ulcer with deformity of the duodenal bulb, stenosis and a crater. Medical management gave only partial relief. On November 10, 1944, a posterior gastro-enterostomy and a subdiaphragmatic section of the vagus nerves was performed. For several weeks after operation, the anastomosis functioned poorly. However, after two months he was able to eat regularly without distress, and by June, 1945, he gained 30 pounds in weight. At this time he was eating a regular diet, without powders, and had no epigastric pain.

M. B. (Unit No. 285298), a 56-year-old white male, was first seen in this clinic on June 20, 1942. Twelve years before he began to have epigastric distress, consulted a physician who made a diagnosis of duodenal ulcer. He was placed on medical management and did fairly well until ten days before entering the hospital, when he developed severe epigastric pain and had a massive hemorrhage. Subsequently, roentgenologic studies showed a duodenal ulcer with a large crater. Roentgenotherapy to the stomach was given and considerable improvement resulted. In November, 1942, he developed obstructive symptoms and a posterior gastro-enterostomy was performed. He was well



for one year following this operation but then symptoms recurred, and roentgenologic examination revealed a gastrojejunal ulcer. Medical management failed to give relief.

On November 8, 1944, the gastro-enterostomy was taken down and on November 24, 1944, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery from both operations was uneventful and when last seen in June, 1945, he was entirely symptom-free and eating a regular diet without alkalies.

J. W. (Unit No. 293108), a 60-year-old male, was first seen in the clinic on September 15, 1942. He gave a history of epigastric distress for the previous 25 years. In 1936, a gastro-enterostomy was performed. Epigastric distress recurred in 1940, and roentgenologic examination revealed a gastro-enterostomy and just above it, a large gastric ulcer. The ulcer was visualized with the gastroscope. Roentgenotherapy to the stomach was given and, on December 22, 1942, the ulcer disappeared, was not demonstrated on either roentgenographically or on gastroscopic examination. In August, 1943, symptoms recurred and the ulcer reappeared on the roentgenogram and on gastroscopy. Strict management was instituted with some decrease in the size of the ulcer but this increased again in the latter part of 1944.

On November 27, 1944, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery was uneventful but was complicated by persistent pain in the region of the incision, which has continued to the present. Roentgenologic examination, March 24, 1945, revealed a poorly functioning gastro-enterostomy with a stomal ulcer.

When last seen in June, 1945, the patient was eating fairly well, had little or no epigastric distress but still complained of pain in the chest.

A. W. (Unit No. 346494), a 47-year-old white male, was first admitted to the clinic on November 21, 1944. He complained of epigastric distress which had been present for the previous 15 years, and a diagnosis of a duodenal ulcer had been made. Diet and powders controlled the pain fairly well during this period. Symptoms recurred, however, and two years before entering the hospital, a gastro-enterostomy was performed elsewhere. Following this operation he was well until four hours before admission when he developed pain in his left side and began to vomit blood. The gastric hemorrhage was controlled and, on November 29, 1944, roentgenologic examination revealed a well-functioning gastro-enterostomy with a gastrojejunal ulcer with a crater. On December 11, 1944, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery from the operation was uneventful except for a slight pleural effusion on the left side which did not require tapping. Ulcer symptoms were entirely relieved and roentgenologic examination, January 9, 1945, failed to reveal the crater at the anastomosis. When last seen in February, 1945, he was free from distress, eating a regular diet, and taking no powders.

H. K. (Unit No. 345881), a 38-year-old white male, was admitted to the clinic on November 11, 1944. For the preceding 20 years he had been having intermittent gastric distress following meals. This was partly relieved by food and alkalies. Roentgenologic examination, November 15, 1944, revealed a duodenal ulcer with deformity and a small central crater. Medical management produced little or no effect. On December 27, 1944, a transthoracic supradiaphragmatic vagus section was performed. Recovery was uneventful. Roentgenologic examination, January 11, 1945, showed no change in the ulcer crater. On February 5, 1945, the crater appeared somewhat smaller and by May 10, 1945, it had completely disappeared on roentgenologic examination.

When last seen on May 6, 1945, he was eating a liberal diet, without powders, and without distress.

H. M. (Unit No. 325181), a 30-year-old white male, was first admitted to the hospital on January 12, 1944. Seven years previously he had epigastric pain occurring after meals. Roentgenologic examination was made, with a diagnosis of duodenal ulcer. Medical management produced marked relief but at intervals the epigastric distress recurred. Two months ago, he began to vomit and the abdominal pain became more

severe. On one occasion he had a severe hemorrhage. Roentgenologic examination revealed a duodenal ulcer, with deformity and a large ulcer crater. Roentgenotherapy to the stomach was given and the crater decreased somewhat in size but did not disappear. He did fairly well on medical management but on July 27, 1944, was readmitted to the hospital because of a massive hemorrhage. This was controlled and, December 29, 1944, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery was complicated by pleural effusion which required aspiration. Roentgenologic examination, April 11, 1945, revealed disappearance of the ulcer crater and no obstruction, but a persistent deformity of the duodenal bulb.

When last seen on May 15 he had no epigastric distress, was eating a regular diet and had gained 30 pounds since the operation.

N. K. (Unit No. 330562), a 48-year-old white male, was admitted to the clinics on March 28, 1944. For the preceding seven years he had been having intermittent epigastric pain coming on several hours after meals and relieved by food and alkalis. He passed black tarry stools at intervals but did not vomit blood. In 1942, he was operated upon elsewhere for ulcers of the stomach but the nature of the operation was not determined. The epigastric distress persisted and roentgenologic examination in this clinic, March 30, 1944, revealed a marked ulcer deformity of the duodenal bulb with a central crater. In April, 1944, he was given roentgenotherapy to the stomach and medical management. The symptoms were relieved and the crater disappeared. In December, 1944, the epigastric pain recurred, roentgenologic examination showed marked deformity but no crater. On January 3, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery was complicated by pain in the chest and from gastric distention. When last seen on April 5, 1945, he was eating a regular diet, without powders, and had no epigastric distress. He had gained 20 pounds since the operation.

M. C. (Unit No. 57621), a 54-year-old white male, was first seen in this clinic in 1932. He gave a history of epigastric distress of the ulcer type for the previous 20 years. Roentgenologic examination revealed deformity of the duodenal bulb with marked pyloric stenosis. A posterior gastro-enterostomy was performed. In June, 1934, his ulcer pain recurred, and roentgenologic studies revealed a gastrojejunal ulcer. Medical management gave only partial relief and, in December, 1934, the gastro-enterostomy was taken down. Within a few months his ulcer symptoms appeared again and persisted in spite of rigorous medical management combined with roentgenotherapy to the stomach to decrease gastric secretion. On January 5, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was done. Following operation, he developed gastric distention, and on one occasion aspirated a considerable amount of vomitus. A broncho-pneumonia developed and death occurred on January 13, 1945. Autopsy was not permitted.

E. T. (Unit No. 347888), a 60-year-old white female, was first seen in this clinic on December 13, 1944. She complained of epigastric pain after meals for the previous 15 years. One year ago, a roentgenologic examination was made, with a diagnosis of duodenal ulcer. Symptoms were relieved by medical management, but in July, 1944, she began to vomit. Roentgenologic examination on December 13, 1944, revealed partial pyloric obstruction due to a duodenal ulcer, with a crater. On January 8, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery was complicated by fever which persisted for a week, and a pleural effusion. Following operation, she was able to eat a soft diet without vomiting. No medication was given. Roentgenologic examination on January 30, 1945, showed some improvement in the pyloric obstruction but persistence of an ulcer crater in the duodenum. On May 8, 1945, the pyloric obstruction was markedly improved although the stomach was still somewhat dilated. When last seen on May 12, 1945, she was eating a liberal diet, without medication, and without epigastric distress or vomiting. Her only complaints were occasional sharp jabbing pain in the region of the incision.

R. V. (Unit No. 343287), a 42-year-old white male, was first admitted to the clinic on October 5, 1944. He gave a history of intermittent epigastric distress of the ulcer type for the previous eight months. For the past four months the pain had been particularly severe. Roentgenologic examination revealed a deformity of the duodenal bulb but no crater. Medical management failed to relieve the distress. On January 10, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery from the operation was uneventful, and all epigastric symptoms were immediately relieved. When last seen, March 31, 1945, he was feeling well, eating a liberal diet without distress or medication.

W. H. S. (Unit No. 345905), a 52-year-old white male, was first seen in the clinic on November 13, 1944. For the preceding 26 years he had been having periodic attacks of severe epigastric pain relieved by food and alkalis. In 1929, these attacks began to be associated with vomiting. Roentgenograms revealed a duodenal ulcer. On medical management he remained fairly well until 1938, when the epigastric pain and vomiting became more severe. These symptoms continued and were associated with a loss of 20 pounds in weight during the five months before admission to the clinics. Roentgenologic examination at this time revealed almost complete pyloric obstruction. On January 19, 1945, a posterior gastro-enterostomy was performed, and at this time the vagus nerves were divided immediately beneath the diaphragm. Recovery from the operation was uneventful and during the first three months the patient gained 30 pounds in weight. When last seen March 27, 1945, he was eating a regular diet, without medication, and without epigastric distress.

J. P. (Unit No. 349287), a 54-year-old white female, was admitted to this clinic on January 10, 1945. She complained of intermittent epigastric pain that was relieved by food and alkalis for the preceding eight years. For the past two years this was associated with vomiting and a loss of 35 pounds in weight. Roentgenology examination, January 10, 1945, revealed marked pyloric obstruction probably due to duodenal ulcer but no crater was visualized. On January 19, 1945, a celiotomy was performed by Dr. William Adams which revealed a large duodenal ulcer with adhesions. The esophagus was mobilized and the vagus nerves isolated. A segment, approximately one inch in length was resected from each vagus nerve. An anterior gastro-enterostomy was then performed. Recovery from the operation was complicated by a severe blood transfusion reaction. When last seen, March 30, 1945, she was feeling well, had no epigastric distress and was eating a regular diet, without powders.

W. W. (Unit No. 351791), a 57-year-old white male, was first admitted to this clinic on February 16, 1945. He reported that he had been entirely well until November, 1943, when he developed a severe epigastric pain for which an emergency operation was performed. A perforated duodenal ulcer was found, and closed. He remained well until December, 1944, when he again had a perforated duodenal ulcer for which he was operated upon and which was again closed. He remained well then until February, 1945, when he developed an attack of severe upper abdominal pain with vomiting. Nine days after this attack he was admitted to the hospital for observation. Roentgenologic examination, February 19, 1945, revealed marked deformity of the duodenal bulb and pyloric stenosis of moderate degree. A crater was not demonstrated. On February 23, 1945, a supradiaphragmatic transthoracic section of both vagus nerves was performed. Recovery from the operation was uneventful. When last seen on July 24, 1945, he stated that he had been completely relieved of all ulcer symptoms since the operation. He was eating a liberal diet without distress or vomiting, and took no medication of any kind.

G. P. (Unit No. 328604), a 48-year-old white male, was admitted to the clinic on March 2, 1944. Twenty years before he first experienced abdominal pain accompanied by nausea and vomiting. A diagnosis of duodenal ulcer was made. Medical treatment proved unsuccessful and, in 1925, a gastro-enterostomy was performed. This gave only temporary relief and, in 1939, roentgenologic studies revealed a gastrojejunal ulcer. He

continued to have epigastric distress with occasional episodes of vomiting during the ensuing five years. When he entered the clinic, roentgenologic examination of the stomach, March 8, 1944, revealed a large gastrojejunal ulcer. On April 3, 1944, the gastro-enterostomy was taken down and a subtotal gastrectomy was performed. Symptoms were entirely relieved until February, 1945, when the abdominal pain returned. Roentgenologic examination, February 14, 1945, revealed the reappearance of a very large gastrojejunal ulcer. On March 12, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Immediate relief followed this operation and he was able to eat a liberal diet, without medication. Subsequent roentgenologic studies, April 30, 1945, showed almost complete disappearance of the ulcer crater.

M. S. (Unit No. 204878), a 36-year-old male, was first seen on August 29, 1938. For the past two months he had been complaining of typical ulcer distress and roentgenologic examination revealed a duodenal ulcer, with a crater. Symptoms were controlled for a time on medical management but recurred in 1943, at which time a subtotal gastrectomy was performed. At operation, a chronic duodenal ulcer penetrating into the pancreas was found. Six months after the operation a recurrence of symptoms developed and a gastrojejunal ulcer was demonstrated roentgenologically. Roentgenotherapy to the stomach was then given, with relief of symptoms, and there was apparent disappearance of the ulcer. The ulcer recurred in six months and pain became severe. On March 23, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery was uneventful, and the patient was entirely relieved of ulcer distress. On May 9, 1945, roentgenologic examination failed to reveal any evidence of the gastrojejunal ulcer.

When last seen in June, 1945, he was symptom-free and ate a regular diet, without powders.

W. K. (Unit No. 355373), a 52-year-old white male, was first admitted to the clinic on April 9, 1945. He gave a history of typical ulcer distress for the preceding 15 years. Medical management had usually been successful in providing relief but frequent recurrences of pain and distress occurred. In the four months before entering the hospital the pain had been unusually severe and failed to respond to the usual therapy. Roentgenologic examination revealed a duodenal ulcer, with a large crater. On April 13, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery from the operation was uneventful and was followed by complete relief of his ulcer distress. When last heard from in July, 1945, he was eating a liberal diet, without medication, and experienced no abdominal pain or discomfort.

C. W. O. (Unit No. 4977), a 42-year-old white male, was admitted to the clinics on April 15, 1945. He gave a history of epigastric distress beginning in 1928, at which time roentgenologic examination revealed a duodenal ulcer. Medical management was faithfully carried out and this provided complete relief of all symptoms except during periods of severe mental strain. At this time, the pain recurred and interfered so much with his work as a trial lawyer that further treatment was desired. Roentgenologic examination revealed a deformity of the duodenal bulb but no crater. On April 18, 1945, a transthoracic supradiaphragmatic section of the vagus nerves was performed. Recovery from the operation was uneventful and following this, all of his ulcer symptoms have entirely disappeared. When last seen in July, 1945, he was eating a liberal diet, without medication, and had no ulcer symptoms.

#### CONCLUSIONS

1. Descriptions are given of methods for the division of the vagus nerve supply to the stomach in man by a transthoracic and an abdominal approach.
2. The vagus nerves to the stomach were divided in 30 patients with duodenal ulcers, in two with gastric ulcers, and in seven with gastrojejunal ulcers.

3. A striking and persistent relief of ulcer distress has been almost uniformly secured, with gain in weight, and roentgenographic evidence of healing of the lesions.
4. Section of the vagus nerves had no effect on the secretory response of the stomach to histamine or caffeine but abolished the response to insulin hypoglycemia and a sham meal.
5. The tonus and motility of the stomach were decreased but not abolished by the operation.

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# BLOOD PRESSURE OF RENAL AND OF EARLY AND LATE NEUROGENIC HYPERTENSION DOGS AFTER LOW CERVICAL CORD SECTION\*

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ESSENTIAL DIFFERENCES between experimental neurogenic and experimental renal hypertension have been reviewed and correlated with clinical hypertension and surgical treatment by sympathectomy.<sup>1</sup> The neurogenic hypertension produced by excision of the carotid sinuses and denervation of the cardio-aortic pressure sensitive areas is effected by altering reflex vasomotor regulation. Elevation of the blood pressure may be prevented or eliminated by complete sympathectomy. The renal hypertension produced by constriction of the renal artery or by capsules about the kidney, is effected by an humoral process. Elevation of blood pressure by this mechanism occurs in the presence or in the absence of the paravertebral sympathetic chains. The angiotonin or hypertensin associated with this form of hypertension will constrict a sympathectomized vascular bed.

Evaluation of the relative importance of abnormal blood pressure regulation over the sympathetic nervous system, of abnormal vasoconstriction by renal metabolic products through the blood stream, or of abnormal peripheral resistance effected by vascular arteriolar disease in the patient with hypertension is difficult. The author has suggested that vasomotor instability may initiate hypertension in certain patients and later produce arteriolar disease and a renal humoral mechanism. Should vasomotor instability be an initiating and a perpetuating factor in the hypertensive disease process of a patient adequate sympathectomy might block the initial development or arrest or delay the late developments. Should arteriolar disease be an early factor sympathectomy could offer only minor or secondary benefit.

Reed, Sapirstein, Southard, and Ogden<sup>2</sup> have found that rats with early renal hypertension and rats with chronic renal hypertension respond differently to nembutal anesthesia and to yohimbine hydrochloride. They suggest that "the renal pressor mechanism which initiates experimental renal hypertension is later superseded by a neurogenic mechanism mediated through the sympathetic nervous system." If correct, this observation will be significant. Occasional patients that have had primary kidney disease and have recovered have remained hypertensive and have responded to sympathectomy.

The patient with hypertension often has neurogenic, renal, and arteriolar disease in varying degrees. Further studies related to possible overlaps between varieties of experimental hypertension seem indicated.

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\* Much of this experimental work was done at the University of Chicago under the direction of Dr. D. B. Phemister.

## RENAL AND NEUROGENIC HYPERTENSION

The experiments reported below were undertaken to determine whether an experimental neurogenic hypertension in the dog could effect the development of detectable renal humoral vasoconstriction. Low cervical cord sections were employed to differentiate humoral from reflex vasoconstriction.

The effect of destroying the cord and of pithing the brain of the normal and of the renal hypertensive rat has been reported by Dock and Rytand.<sup>3</sup> Similar studies with the rabbit were reported by Dock.<sup>4</sup> The blood pressure of the rabbits formerly hypertensive exhibited higher elevation of blood pressure after the injection of epinephrine than occurred in pithed normal rats.

Glenn, Child, and Page<sup>5</sup> investigated the effect of low cervical cord section and destruction of the distal segment of cord upon the blood pressure of dogs with hypertension produced by Goldblatt clamps applied to the renal arteries. An immediate drop of pressure occurred that was replaced within five to 25 days by a definite restoration of hypertension levels that approached those observed before destruction of the cord. Glenn and Lasker<sup>6</sup> destroyed the spinal cords below C<sub>6</sub> in normal dogs. Surgical shock with low or imperceptible blood pressure occurred during the first several hours. The blood pressure returned to normal values after two to seven days. Constriction of renal arteries then produced hypertension.

Cord section at C<sub>7</sub> has been employed in six normal dogs, five dogs with renal hypertension, four dogs with neurogenic hypertension of 15 to 22 months' duration, and three dogs with neurogenic hypertension of 122 to 176 days' duration. Chloralose 0.1 Gm./Kg. was administered intravenously before each experiment. Artificial respiration was given routinely through a tracheal cannula. Blood pressures were recorded directly from one femoral or one carotid artery through tubing connected with a recording mercury manometer. Citrate or heparin was used in the tubing fluid. One hundred to 300 cc. of saline was given intravenously during the lower cervical spinal cord to minimize shock. The blood pressure was recorded without disturbing the animal for 10 to 20 minutes after exposure. The spinal cord at C<sub>7</sub> was then quickly frozen with CO<sub>2</sub> and completely transected using sharp scissors. A sponge was placed in the defect. The skin edges were clipped together over the sponge. Further observations were made without disturbing the animal.

### CERVICAL CORD SECTION IN NORMAL DOGS

The blood pressures of six normal dogs were determined by puncture of the femoral arteries. The pressures ranged from 112 to 142, and averaged 132. After chloralose anesthesia they were again determined by needle puncture. The blood pressures ranged from 132 to 148, and averaged 138. After cannulae were inserted into the trachea and the femoral artery and the cord were exposed the blood pressures ranged from 130 to 152, and averaged 144. The spinal cord was then frozen and severed at C<sub>7</sub>. Twenty minutes

later the pressures ranged from 74 to 100, and averaged 89. Sixty minutes after cord section the pressures ranged from 50 to 80, and averaged 71. The pressures of five observed two hours ranged from 70 to 80, and averaged 77. Three observed longer than three hours had further lowering to 64, 68, and 70.

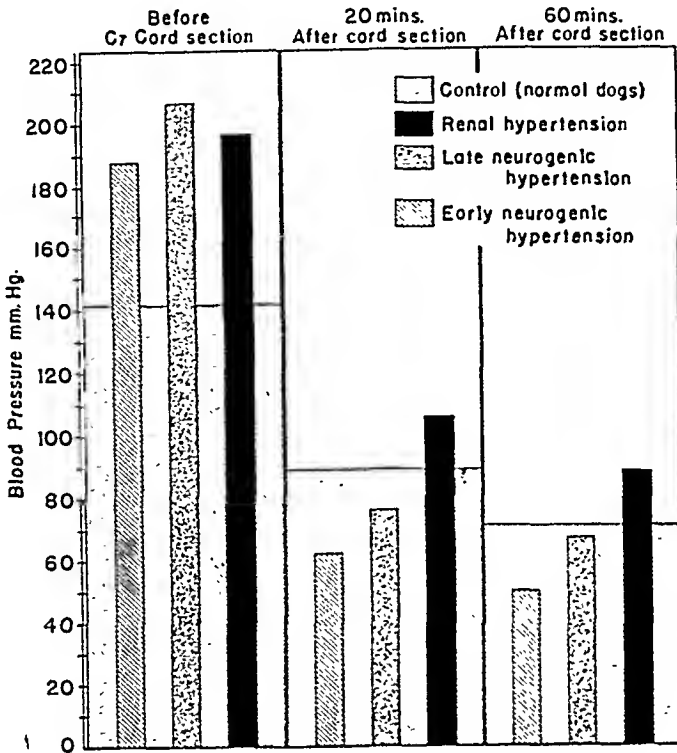


FIG. 1.—The average blood pressure of five dogs with renal hypertension, four dogs with early neurogenic hypertension, and three dogs with late neurogenic hypertension are compared with the average blood pressure of six normal dogs before and 20 minutes and 60 minutes after cord section. Elimination of central reflex vasopressor control reduces the blood pressure of dogs with neurogenic hypertension below control values and leaves the pressure of dogs with renal hypertension above control values.

#### CORD SECTION IN RENAL HYPERTENSION DOGS

Five dogs with renal hypertension produced by removing one kidney and applying tight linen capsules about the other were sacrificed in similar low cervical cord section experiments. Blood pressures by puncture of the femoral artery ranged from 202 to 216, and averaged 212. Blood pressures by artery puncture under anesthesia ranged from 196 to 228, and averaged 213. After preparation and just before freezing and division of the cord the pressures ranged from 180 to 215, and averaged 197. Twenty minutes after severing the cord the pressures ranged from 80 to 170, and averaged 116. Sixty minutes after cord section the pressures ranged from 50 to 138, and averaged 88. Two hours after section the pressures ranged from 40 to 146, and averaged 79. Saline solution was later given intravenously to four of the dogs in amounts varying from 150 to 300 cc. It effected elevation of the pressures from a range of 40 to 72, and an average of 61, to a range of 90



to 128, and an average of 114. This elevation persisted during the further period of observation of 0.5 to one hour. The fifth dog received no saline and had a pressure 2.5 hours after cord section of 140. The blood pressures of all dogs at the time of sacrifice 2.5 to three hours after low cervical cord section ranged from 90 to 140, and averaged 120.

#### CORD SECTION IN EARLY NEUROGENIC HYPERTENSION DOGS

Four dogs with neurogenic hypertension produced by excision of both carotid sinuses, division of one vagus-depressor-sympathetic trunk, and division of the other depressor-sympathetic trunk were sacrificed in similar low cervical cord section experiments. The hypertension had been present 122 to 176 days. Blood pressures by puncture of the femoral artery ranged from 200 to 256, and averaged 224. Pressures by artery puncture after anesthesia ranged from 174 to 260, and averaged 220. After preparation and just before freezing and transection of the low cervical spinal cord the pressures ranged from 164 to 200, and averaged 188. Twenty minutes after cord section the pressures ranged from 52 to 68, and averaged 62. Sixty minutes after section they ranged from 44 to 54, and averaged 50. A further decline of pressure was observed in dogs observed longer than one hour.

#### CORD SECTION IN LATE NEUROGENIC HYPERTENSION DOGS

Three dogs with neurogenic hypertension were observed 15, 21, and 22 months before being sacrificed in cord section experiments. The arterial blood pressures were 238, 234, and 230 before and 194, 242, and 230 after anesthesia. The pressures after preparation and before cord section were 210, 206, and 212. Twenty minutes after section they were 80, 70, and 78. Sixty minutes after section they were 86, 70, and 50. The pressure of one dog observed 2.25 hours fell from 86 at one hour to 70.

DISCUSSION.—The blood pressure of normal dogs and of dogs with renal or neurogenic hypertension is little altered by chloralose anesthesia or by the operative preparation for cord section. Persistence of neurogenic hypertension during anesthesia, sedation, and natural sleep has been described.<sup>7</sup> Anesthetics or rest with sodium amytal, or other sedation, does not differentiate experimentally or clinically between reflex, humoral, or vascular disease components of hypertension.

The possible relationship between these elements in animals, or in patients, with hypertension is important. Elimination of all significant vasoconstrictor pathways by a total sympathectomy should block a reflex disturbance but should not correct renal or vascular disease. Low cervical cord section experiments have differentiated experimental renal from experimental neurogenic hypertension. The cords were frozen with CO<sub>2</sub> before section to reduce the immediate effect of stimulation of the cord by transection.

The effect of section of the low cervical spinal cord upon the blood pressure of normal dogs, renal hypertension dogs, and early and late neurogenic

hypertension dogs is illustrated in Figure 1. The dogs with renal hypertension exceeded the blood pressure of the normal dogs before cord section and also 20 and 60 minutes after cord section. This is compatible with the presence in the blood stream of angiotonin, or hypertensin, acting peripherally independent of central vasoconstriction. Two hours after elimination of central vasomotor tone by cord section 150 to 300 cc. of saline elevated the average pressure of five renal hypertension dogs from 61 to 114. The higher pressure level persisted during the last half-hour to one hour of observation. This elevation is also compatible with the presence in the animal of an humoral vasoconstrictor capable of increasing blood pressure as the conditions of the circulation of the blood are improved.

Low cervical cord section in animals with early and late neurogenic hypertension produced a lowering of pressure below the levels observed in normal dogs. This lowering was most pronounced in animals with hypertension present 122 to 176 days. It was also significant in animals with hypertensions of 15, 21, and 22 months' duration. A moderate hypertension can be produced by renal vasoconstriction.<sup>8</sup> Renal denervation, however, does not alter experimental neurogenic hypertension.<sup>9</sup> The relative importance of a renal factor in experimental neurogenic hypertension has not been determined. The cord section experiments would indicate that loss of the abnormally increased reflex vasopressor influences to the entire body left them with less than normal intrinsic and humoral peripheral vascular tone. Humoral vasoconstrictors, if present, were not able to maintain blood pressures equivalent to those of normal dogs.

#### CONCLUSION

The evidence obtained by section of the cervical spinal cord at C<sub>7</sub> indicates that neurogenic hypertension early and after 15, 21, and 22 months does not develop a detectable humoral vasoconstrictor influence like that developed in renal hypertension by angiotonin or hypertensin.

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## CUTIS GRAFTS

CLINICAL AND EXPERIMENTAL STUDIES ON THEIR USE AS A REINFORCING  
PATCH IN THE REPAIR OF LARGE VENTRAL AND INCISIONAL HERNIAE

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SINCE LOEWE'S REPORT, in 1913, cutis grafts have been sporadically adopted for two purposes: (1) In the field of plastic surgery where the cutis is utilized to fill in tissue defects; and (2) in the operative treatment of hernia where patches of cutis are applied to strengthen the repair.

Cutis may be defined as the deeper layers of the skin which have been stripped of their epidermal covering. Anatomically, this includes approximately the deeper three-quarters of the thickness of the skin, the entire skin averaging about 1 mm., or 40/1000 inches, in depth. Histologically, cutis comprises the dermal layer with no epidermal covering, but with sebaceous and sudoriferous glands and occasional hair follicles as well as some of the underlying subdermal fat.

Reports in the literature on the use of cutis grafts, particularly as applied to the repair of hernia, include the following:

1. Loewe (1913) reported the use of cutis grafts in five cases of hernia and one of tendon repair. In describing the technic for removal of the graft, this author stated that the skin was removed with a scalpel in the manner of any full-thickness graft. The epidermis was then abraded away by scraping, as one would clean a carrot. The remaining tissue was then sutured over the defect under tension and the donor area was allowed to granulate and heal by second intention.

2. Rehn (1914) reported experiments on the use of cutis material. Strips of twisted cutis were used as insert grafts in the Achilles tendon of dogs. Rehn stated that under the influence of continual tension, a gradual degeneration of epithelial elements occurred, and that the tissue assumed the appearance and functions of normal tendon in about ten weeks.

3. Loewe (1929) extended his observations on the clinical use of cutis grafts to almost 100 cases.

4. Straatsma (1932) used buried cutis grafts for saddle-nose repair.

5. Uihlein (1939) reviewed the work of Rehn and presented 104 cases done in the latter's University Clinic in Freiburg since 1928. Eighty of these operations were for hernia.

6. Cannaday (1942) was the first writer to report the use of cutis grafts in hernial repair in this country, presenting 14 such cases. In 1943, this author made a later report, adding to his original cases and bringing the total to 37, 27 of which were operations for hernia.

7. Swenson (1943) reported two incisional herniae which were repaired with cutis graft reinforcement.

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8. Scola (1944) reported the use of cutis grafts in the repair of two recurrent inguinal herniae and three incisional herniae. The cutis grafts were prepared by Scola's special method (*vide infra*) and in the operations on two of the incisional herniae formed the chief support, it being stated that "the fascia could not be closed."

9. Cannaday (1944) reported a total series of 107 operations utilizing cutis grafts, 56 of which were operations for hernia. Cannaday is at present the chief advocate of this technic in this country and expresses his position by stating: "Cutis may be used for any and every purpose for which fascia has been used, with the expectation of better results. . . . After this clinical experience with the uses of cutis (derma) in repair surgery, I am convinced that it is one of the most useful autoplasic repair materials that we have, that it is superior in strength to fascia lata and of much easier availability; that success in its use can be expected in a large percentage of cases; that it is of especial value in the surgical repair of large incisional herniae."

### METHOD OF OBTAINING CUTIS

Cutis is obtained by removing a full-thickness skin graft and, in turn, separating the latter into its deep larger (cutis) and superficial layer (epidermis). The cutis is used for the hernial repair and the epidermis is either discarded (by some authors) or utilized to cover the donor area as a skin graft. These methods can be classified as follows:

1. *Original Loewe Method (1913)*: A full-thickness graft is removed with a scalpel and then the epidermis is scraped off the graft with a razor. The donor site is allowed to granulate.
2. *Rehn Method (Uihlein, 1939)*: A Thiersch graft is removed from the thigh and in the exposed bed a cutis graft of desired size is cut. The Thiersch graft is presumably resutured over the defect.
3. *Rehn's "Türflügel" Method (Uihlein, 1939)*: The cutis is cut from a portion of abdominal wall to be discarded (as when doing a lipectomy in association with the repair of an incisional hernia). This obviates all necessity for closing the donor site. The method is only applicable to obese patients with incisional herniae, and has the objection that the neighboring skin is often atrophic and contains striae.
4. *Dermatome Flap Method of Swenson and Author (1943)*: This technic is similar to the Rehn method (No. 2 above) except that the epidermis is cut off with a dermatome and one end is left attached. This saves time and allows for a neater closure of the donor wound.
5. *Method of Scola (1944)*: A full-thickness dermatome flap (0.040 to 0.050 inch) is cut and one end left attached. Fresh glue is applied to the dermatome which then shaves the epidermis off the full-thickness flap at a depth of 0.008 inch, beginning at the attached end. The underlying cutis is then detached for use and the free piece of epidermis sutured over the donor defect. This method has the advantage of cutting the cutis so that not only its superficial, but its deep surface is smooth and regular. This also represents the first

method where the cutting of the cutis is entirely mechanically controlled and where its thickness is known, at least within the limits of accuracy of the dermatome.

6. *Split-split Method*: In 1945, Zintel, of Philadelphia, reported the split-split method for increasing the yield of skin grafts from donor sites of limited size in extensive burns. The principle of the method is simply the splitting of a Padgett skin graft into two layers of equal thickness on the drum by resetting the blade. For adults the entire thickness was 0.020 to 0.028 inches and the two component halves were 0.010 to 0.014 inches. The idea presented itself to the author of utilizing Zintel's method for the preparation of cutis grafts. A thicker original setting (about 0.040 inches or more) is used and then the epidermis is cut off at a depth of about 0.010 to 0.020 inches and sutured on the donor area. The inner cutis layer is used for reinforcement of the hernia. The cutis so obtained is of known and regular thickness, but if the dermatome has a loose axle, tends to be too thin.

#### ANALYSIS OF CLINICAL CASES

Eleven patients, nine with ventral incisional herniae and two with epigastric herniae, were operated upon with silk closure of the fascia reinforced with an overlying patch of cutis. These operations were performed during the two-year period from May 13, 1943, to February 28, 1945. All operations except one (Case 4, done by Dr. George Duncan, Resident in Surgery at the Johns Hopkins Hospital) were performed by the author. Cases 1 and 2 were seen at the Henry Ford Hospital, and the remainder of the operations were performed at the Johns Hopkins Hospital.

*Age*: The patients varied in age from 36 to 56 years, with an average of 44 years.

*Sex*: Eight of the patients were females and three were males.

*Weight*: In ten cases where the weight was given all but one exceeded 205 pounds, with the heaviest patient (Case 4) weighing 263 pounds.

*Previous Operation*: Nine patients had previous operations as follows: Appendicectomy, with drainage—3 cases, cholecystectomy—2 cases, pelvic operations—3 cases, operation for "swallowed glass in intestines in 1919"—1 case. These operations had all been performed before 1941.

*Duration of Hernia*: The onset of the hernia varied from 1924 to 1943, with an average date of onset of 1936 (seven years before this series).

*Previous Attempts at Repair*: This had been done in five of the 11 cases, four of these operations being performed elsewhere. The exception (Case 2) deserves further explanation. On December 8, 1942, an hysterectomy and Mayo repair of a para-umbilical hernia was performed by the author. Six months later a swelling was diagnosed as a recurrence and operation was performed. Before starting the abdominal part of the operation, a strip of cutis was taken from the right thigh by the dermatome flap method. Afterwards, the abdominal operation revealed no recurrent hernia and only an aseptic serocele containing clear fluid. The wall of the serocele was excised and the cutis used

to reinforce the already strong previous repair. Two years later the patient presented no signs of recurrence and had no symptoms referable to the operation.



FIG. 1.—Incisional hernia in a 56-year-old female following hysterectomy in 1932. Onset in 1933, previous attempt at repair elsewhere in 1935. Cutis graft repair September 30, 1944 (Case 8). (A) and (B). Front and side views before operation. (C) and (D). Front and side views six weeks after operation. The healed donor area on the right thigh is seen in (D).

*Size and Description of the Hernia:* In all instances the well-known fact that incisional hernia rings are smaller than they appear to be externally was demonstrated. However, rings 6x10, 6x13, 5x5, 9x9, 6x9, 9x11, and 13x13 cm.

were noted. All sacs came straight out or pointed to the right. In two cases two rings were noted. Representative herniae with results after operation are shown in Figures 1 and 2.



FIG. 2.—Incisional hernia in a 45-year-old male following appendicectomy, with drainage, elsewhere in 1940. Cutis graft repair February 28, 1945 (Case 11). (A) and (B). Front and side views before operation. (C) and (D) Front and side views four weeks after operation.

*Anesthesia:* In five cases gas-oxygen-ether was used alone, and in one case each was supplemented with pentothal and with spinal. In one case continuous spinal anesthesia was used.



*Incision:* In eight cases a transverse incision was used, in two, a vertical, and in one, the previous right subcostal incision was followed.

*Source of Graft:* The right thigh was used in ten cases and the part of the abdomen to be discarded after lipectomy was used in another case.

*Associated Lipectomy:* This was done in nine of ten cases where there is a statement in this regard.

*Taking of the Cutis:* This was done by three methods as follows:

(a) Dermatome flap method, used in Cases 1-5 and 7 and 8. This method is simpler and more rapid than any of the older technics. It is, however, more time-consuming than the two methods listed below. The under side of the cutis, being cut by hand with a scalpel, is of necessity irregular.

(b) Scola method, used in Case 6. This technic is rapid, but requires a very sharp blade and has the objection that it is difficult to cut the epidermis off the edges of the cutis, and this wastes a considerable portion of the graft.

(c) Split-split method, used in Cases 9-11. The quickest and most satisfactory method. (One of our dermatomes has an axle with considerable looseness and is not accurate enough to cut split-split grafts of any sort).

*Thickness of the Epidermis:* This varied from 9 to 20 thousandths of an inch, with an average of 13 thousandths in ten cases. The donor sites healed with no appreciable differences, as did the hernia wounds. A section of epidermis is shown in Figure 3.

*Thickness of the Cutis:* This can obviously be measured only when the Scola or split-split methods are used. In four cases it varied from 20 to 31 thousandths of an inch, averaging 24 thousandths. A section of cutis is shown in Figure 4.

*Position of the Cutis Graft:* In one case the cutis was placed right side up and in seven cases it was placed upside down (fat side up). In one instance (Case 7) a double thickness of folded cutis was used, the fat side being inside on each leaf. No difference in the results was noted. The reason for putting the nonfatty side down was the belief that it would unite more easily with the fascia beneath. A photograph of a patch of cutis sutured in place is shown in Figure 5.

*Cultures:* Cultures of the epidermis taken in four cases were all negative. These varied from the thinnest (0.009 inch) to the thickest (0.020 inch) slices of epidermis. In six cases the cutis was cultured and the results were negative in four instances (Cases 6, 7, 9 and 10). In two instances, as will be discussed later, the results were positive (Cases 8 and 11).

*Closure of the Fascial Defect:* This was transverse in five instances, vertical in five instances, and oblique in one instance. This corresponds to the skin incisions except that in three cases a transverse skin incision was followed by a vertical fascial closure. Transverse skin incisions were chosen because of the frequent desirability of lipectomy. Silk closure with interrupted sutures and, if possible, imbrocation of the fascial layers was used routinely. In no case did a fascial defect remain. In one case the anterior rectus sheath was split vertically on each side and folded over the suture line.

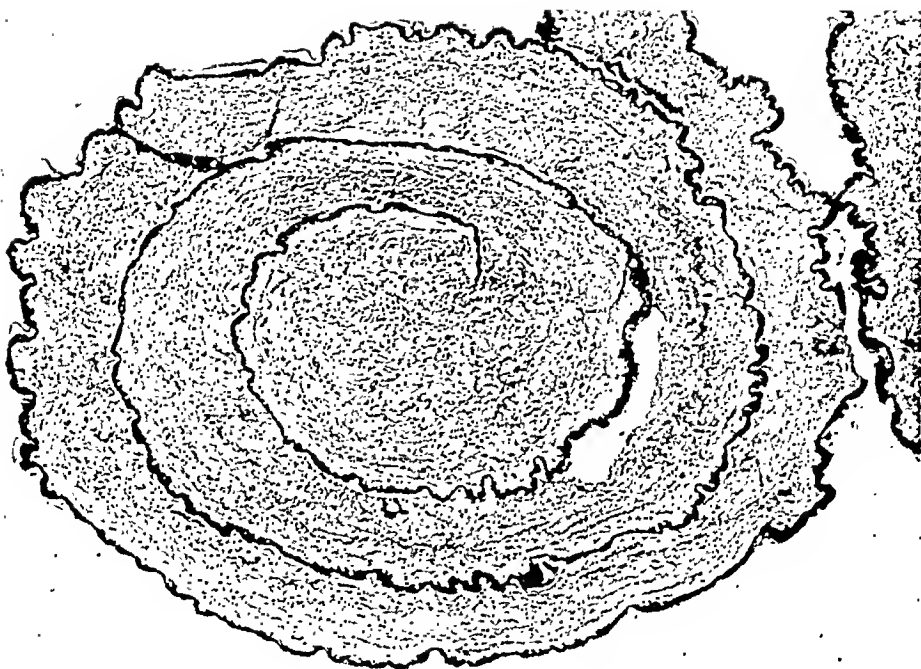


FIG. 3.—Discarded rolled-up epidermis in Case 10. The epidermis was removed at a depth of 0.020 inch by the split-split method from the portion of the abdominal wall to be discarded after lipectomy. Note the atrophic epidermis which could have been adequately removed by a more shallow excision.

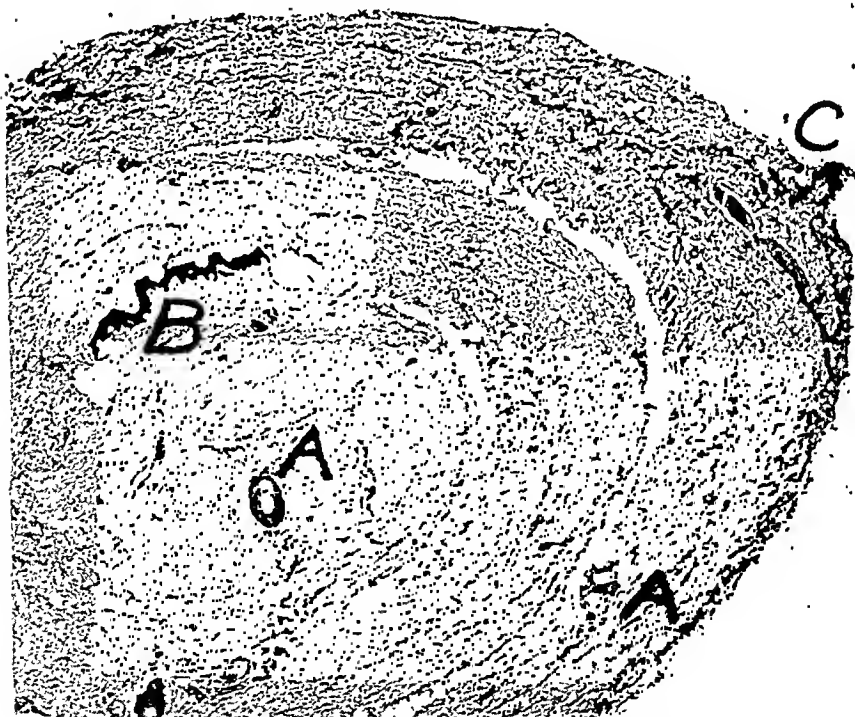


FIG. 4.—Portion of rolled-up cutis in Case 11. A full-thickness graft was removed at a depth of 0.040 inch (1 mm.) and the epidermis taken off by the split-split method at a depth of 0.014 inch, making the resultant cutis 0.026 inch thick. Note hair follicles and glands (A); border of epidermis (B) at edge of graft (such a border was removed from the piece of cutis that was buried); and an island of epidermis (C) which might have been overlooked and buried.

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*Histologic Examination:* Sections of the epidermis removed in Case 10, at a depth of 20 thousandths of an inch, show that this depth of cutting was not necessary (Fig. 3). Sections of excess cutis in six cases all showed epithelial elements. This indicates that such an inclusion cannot be entirely avoided by cutting the epidermis deeper, unless the cutis itself is made so thin that it is of little value for supportive purposes.

**Case 6.**—Cutis: In a low power field several hair follicles and a few sebaceous and sudoriferous glands are identified. These occur at various depths in the cutis and are not just at the superficial edge. (Epidermis 0.009 inch; cutis 0.031 inch additional).

**Case 7.**—Cutis: Rather frequent hair follicles are seen at various depths in the cutis. One sebaceous gland, several sudoriferous glands and two epidermal pockets are identified. (Epidermis 0.012 inch; cutis cut by scalpel.)

**Case 8.**—Cutis: No hairs or hair follicles are seen, but there are numerous sudoriferous glands especially near the superficial surface of the cutis. These are, however, seen occasionally in the depths of the cutis. One sebaceous gland is identified and one patch of epidermis is seen in the surface; this latter is possibly the edge of a hair follicle. (Epidermis 0.011 inch; cutis cut by scalpel.)

**Case 9.**—Cutis: Few epithelial elements are present. The base of one hair follicle is seen at the outer surface and a few sudoriferous glands at various levels. No patches of epidermis or sebaceous glands are identified. (Epidermis 0.020 inch; cutis 0.020 inch additional.)

**Case 10.**—Cutis: There are few epidermal elements present, but one hair follicle and several sudoriferous glands are seen. (Epidermis 0.020 inch; cutis 0.020 inch additional.) It is of interest that this cutis as well as that from Case 9 both had the most (0.020 inch) epidermis removed, indicating that there is at least a quantitative reduction in the amount of epithelium left behind, even though there is not a qualitative disappearance of the same.

**Case 11.**—Cutis: Several hair follicles and glands are identified, as shown in Figure 4. At the edge of the cutis is a portion of unremoved epidermis. This remained attached because of rolling of the edge during the split-split process. The piece of epidermis was large enough to be visible to the naked eye and was removed from the portion of the cutis used for the operation. A smaller piece of epidermis near the center of the cutis was probably due to a glue blister on the dermatome. Such a piece might easily have been buried in the patient's wound. (Epidermis 0.014 inch; cutis 0.026 inch additional.)

*Results:* Ten of the 11 patients showed no recurrence of the hernia after the short follow-up of from one to 22 months (average eight months). All but one follow-up was by direct examination, the exception being by letter. Case 10 (weight 259 pounds) which at operation was more a diastasis than an hernia still has some diastasis at the upper end of the incision on straining. This patient and that in Case 9 still complain of a slight pain at one end of the operation. The other nine patients have no complaints referable to the operation. The donor site is well healed in all but the patient in Case 5 who was last seen only one month after operation.

**OBJECTIONS TO THE USE OF CUTIS GRAFTS IN THE REPAIR OF HERNIAE**  
These can be summarized as follows:

(1) *Introduction of infection from bacteria contained in the hair follicles*

and sudoriferous glands of the cutis. In published reports of clinical cases, infection does not seem to be a frequent postoperative complication. In Uihlein's series (1939) of 104 cutis graft operations, 15 wound infections (15 per cent) developed. The personal clinical cases cited above also substantiate this experience, there being only one case of wound infection (Case 11), and in this case the wound culture when the infection had developed (*hemolytic Staphylococcus albus*) did not reveal the same organism as did the cutis culture at the time of operation (heavy growth of *beta Streptococcus*, Lancefield Group B). The results of cutis cultures in the five other tested clinical cases were as follows: Negative in four cases and positive in Case 8 (moderate growth of *hemolytic Staphylococcus albus* and *Staphylococcus aureus*). In four cases, portions of the epidermis removed from the top of the cutis were cultured with no growth resulting in any instance.

The animal experiments described below were formulated to further test this aspect of the subject:

(2) *Persistence of Epithelial Elements with Resultant Cyst Formation:* Several writers, particularly Davis and Traut (1926), and Zimches (1931), have studied the effects of burying sheets of full-thickness skin in dogs. Cysts resulted after three to four weeks, and tended to persist. Peer and Paddock (1937) studied the effects of burying fragments of cutis in human beings, with histologic observations at intervals of from one week after operation. The cutis grafts were prepared by taking a Krause full-thickness skin graft from the abdomen. "The epidermis was shaved from each section as completely as possible with a sharp No. 11 Bard-Parker knife blade, and the remaining dermis and fat were inserted beneath the skin of the chest with the dermis outermost." This method did not yield a true cutis graft because the authors admitted and their sections demonstrated that "in spite of attempted complete removal of the epidermis, some epidermis remained." This gave rise to cysts containing horny material and some hairs. Sebaceous glands were noted only in the implants of one week's duration, hair follicles only up to three weeks, while sweat glands persisted for a year, but in later sections they were in the process of degeneration and fibrous replacement. The cutis grafts fused with the surrounding connective tissue, but the granulation tissue surrounding the implant was of the chronic inflammatory type with lymphocytes, macrophages, epithelioid cells, often giant cells, and in some cases granulomatous nodules. The latter contained elements resembling hairs in some instances.

The animal experiments described below were formulated to further test the importance of persistence of epithelial elements. Furthermore, since the advent of the dermatome, there is now a means of measuring accurately the exact depth of cutis used and epidermis removed, as was not the case in Peer and Paddock's experiments.

(3) *Bridging a Fascial Defect is Seldom Necessary in the Repair of Herniae:* This objection also holds for the use of fascial grafts. The author has never seen a ventral or incisional hernia where the fascial layers could

not be brought together. The cases of Scola (1944), where large defects in the fascia remained and these were covered with cutis, seem incomprehensible or are very rare. Swenson and Harkins (1943) reported that in recurrent inguinal herniae silk gives just as good if not better results than fascia. The indication for cutis would seem to be, therefore, as a reinforcement of an already carefully executed silk (or other nonabsorbable material) repair.

(4) *Reinforcement is not Necessary in Small Herniae and Increases the already Long Operating Time too much in Large Herniae.* This objection is valid in many cases, but, on the other hand, a large group of moderate sized herniae do appear to be better supported with a reinforcing patch of cutis. When the cutis is taken by the split-split method, the additional time required is about 20 minutes. When one of the combined dermatome-manual technics is used, up to 50 minutes may be consumed in taking and applying the graft and in suturing the donor site. When two teams are available, this additional time can be cut down to almost nothing. The amount of blood lost by the additional procedure is, on the other hand, quite small.

#### EXPERIMENTAL STUDIES

Cutis grafts were implanted in 25 experiments upon 14 dogs. The grafts were taken by the various methods outlined in discussion of the clinical cases and sections and cultures were made of the epidermis and of the cutis. Necropsy studies were made as to the gross and histologic fate of the grafts. All experiments were undertaken under ether anesthesia, and with routine aseptic technic.

**Experiment 1.**—(Dog 1, female, 9.8 Kg.) October 16, 1944. *Abdominal Wall Implant:* A piece of cutis 4 cm. square was removed from beneath a dermatome graft of 0.014 inch with a scalpel and was implanted over the rectus sheath on the right side with the epidermal side up. Death occurred on the 22nd day from no apparent cause and necropsy showed no definite wound infection. There were no evident gross cysts, but histologic section revealed numerous horny clusters separated from the rectus sheath by a fatty layer.

**Experiment 2.**—(Dog 1) *Abdominal Wall Implant:* A similar graft was placed epidermal side down on the left rectus sheath. Gross cysts were present at necropsy and histologic examination (Fig. 6) revealed a picture similar to that in Experiment 1, except that the horny clusters pointed towards the rectus sheath rather than away from it.

**Experiment 3.**—(Dog 2, female, 10.2 Kg.) October 23, 1944. *Abdominal Wall Implant:* A small cutis graft similar to those in Experiments 1 and 2 was placed over the muscular fascia of the lower lumbar region with the epidermis down. The wound was well healed, as was the donor area, on September 21, 1945 (11 months) when the animal which was in good shape was sacrificed. The graft was still present, clean, and was fused with the surrounding tissues. Histologic section revealed hairs, small epithelial-lined cysts, and clusters of epithelial cells, all with practically no sign of surrounding inflammatory reaction.

**Experiment 4.**—(Dog 2) *Abdominal Wall Implant:* A similar graft was placed in the upper lumbar region with the epidermis up. The wound is well healed and the graft clean and similar to that in Experiment 3 except that it was less demarcated from the surrounding tissue on necropsy. Histologic section revealed numerous but scattered hairs and hair roots with no sign of surrounding inflammatory reaction.

**Experiment 5.**—(Dog 3, female, 9.5 Kg.) November 15, 1944. *Iliac Artery Ligation:* A cutis graft was removed with a scalpel from the back after taking off the

epidermis at a depth of 0.010 inch by the dermatome flap method. The epidermis shows numerous transected hair follicles as seen in Figure 7. Numerous hairs and glands were present throughout the cutis and, in fact, were quite numerous in the fatty tissue beneath it as seen in Figure 8. The number of epithelial elements was much larger than in the human cases (Fig. 4). Two strips of cutis were used to ligate the right common iliac artery twice. Death occurred from inanition without gross wound infection on April 9, 1945 (five months). The artery was occluded, but considerable sebaceous material was about the site of the ligature.



FIG. 5.—Cutis graft (the white patch in the wound bed) in place (Case 1). The cutis graft was taken from the right thigh by the dermatome flap method and is used as a patch over the suture line of a modified Mayo-type repair of an incisional hernia. This hernia occurred in a male 40 years of age, and was situated in the right subcostal region following a cholecystectomy in 1940. One previous attempt at repair had been made elsewhere.

**Experiment 6.**—(Dog 3) *Abdominal Wall Implant*: A large piece of the cutis (9 x 4 cm.) graft was placed over the right rectus sheath with the epidermal side down. At necropsy, this graft was not completely adherent to the rectus sheath.

**Experiment 7.**—(Dog 3) *Abdominal Wall Implant*: A smaller piece of the cutis placed over the left rectus with the epidermal side up was well healed and scarred at necropsy, but histologic sections showed hairs and chronic granulation tissue.

**Experiment 8.**—(Dog 3) *Abdominal Wall Implant*: A small piece of cutis was placed between the peritoneum and the properitoneal fat with the epidermal side towards the peritoneum. At necropsy, it was puckered and sebaceous-like material was grossly present.

**Experiment 9.**—(Dog 4, female, 11.8 Kg.) November 20, 1944. *Iliac Artery Ligation*: A cutis graft was obtained from the back by the split-split method (epidermis 0.008 inch, and cutis 0.032 inch additional). Hairs and attached sebaceous glands as well as sudoriferous glands made up a good portion of sections of the cutis. These were just as plentiful in the middle of the cutis as on its superficial edge, but less so at its deep margin. The left common iliac artery was tied with two strips of cutis 1 cm. wide. It tied more easily than when the cutis was cut by hand (Experiment 5). The lumen of the iliac artery was quite intact and no remnant of the cutis was found when the dog was sacrificed on June 27, 1945 (seven months).

**Experiment 10.**—(Dog 4) *Abdominal Wall Implant*: A portion of cutis was placed under the left external oblique over the celiotomy suture line with the epidermal side out. At necropsy, a sinus came from this wound, and there was a large collection of hairs at the site of the graft, with acute infection demonstrated grossly and microscopically. There was no weakness of the abdominal wall.

**Experiment 11.**—(Dog 4) *Abdominal Wall Implant*: A piece of cutis was placed over the left external oblique in the upper abdomen with the epidermal side in. It was not adherent at necropsy to the external oblique, but was to the subcuticular structures. Hair, sebaceous material and granulation tissue were present, grossly and microscopically.

**Experiment 12.**—(Dog 5, male) November 20, 1944. *Abdominal Wall Implant*: A cutis graft was obtained from the chest by the split-split method (epidermis 0.016 inch, and cutis 0.024 inch additional) and placed epidermal side down over the right external oblique. A piece of the epidermis when sectioned showed transected hair follicles as did the cutis strip. The animal died from pneumonia on the seventh day. The wounds on the right side were infected (see also Experiment 14) but were not on the left (see Experiment 13). The cutis seemed to be attached, however.

**Experiment 13.**—(Dog 5) *Abdominal Wall Implant, Double Thickness*: Another strip of cutis was sutured after folding it double with the epidermal side inside beneath the left external oblique. At necropsy this graft was clean and no infection or sebaceous material was noted grossly. Microscopically, a small abscess, 0.5 x 4.0 mm., containing polymorphonuclear neutrophils was present as well as sebaceous material and hairs.

**Experiment 14.**—(Dog 5) *Homologous Graft, Abdominal Wall Implant, Double Thickness*: A piece of cutis obtained from another dog that died from anesthesia, and taken by the same technic, was placed without suturing over the right external oblique after folding double with the epidermal side out. At necropsy this graft was infected, but firmly attached.

**Experiment 15.**—(Dog 6, female, 10.5 Kg.) November 27, 1945. *Abdominal Wall Implant, Rolled Up*: A cutis graft 8 x 11 cm. was taken from the lower chest by the split-split method (epidermis 0.020 inch, and cutis 0.020 inch additional). Half of this was rolled up with the epidermal side outside under the skin of the right groin through a midline incision. Sections of epidermis and cutis were similar to those in Figures 7 and 8. The animal was sacrificed June 27, 1945 (seven months). The wound was clean and no evidence was found of the cutis graft. The donor area to which the epidermis had been resutured was well healed, but practically hairless.

**Experiment 16.**—(Dog 6) *Abdominal Wall Defect*: The other piece of cutis fell on the floor, but was washed in saline and was sutured in a 10 x 3 cm. excised defect of the left lower abdominal musculature (oblique muscles and rectus abdominus) against the transversalis muscle and peritoneum with the epidermal side down. At necropsy the graft was well fixed and clean. Sections showed no sign of infection or epithelial





FIG. 6.—Necropsy specimen of cutis graft from Dog 1, taken 22 days after operation. The graft was placed upside down on the rectus abdominis muscle. Note the numerous horny nests.

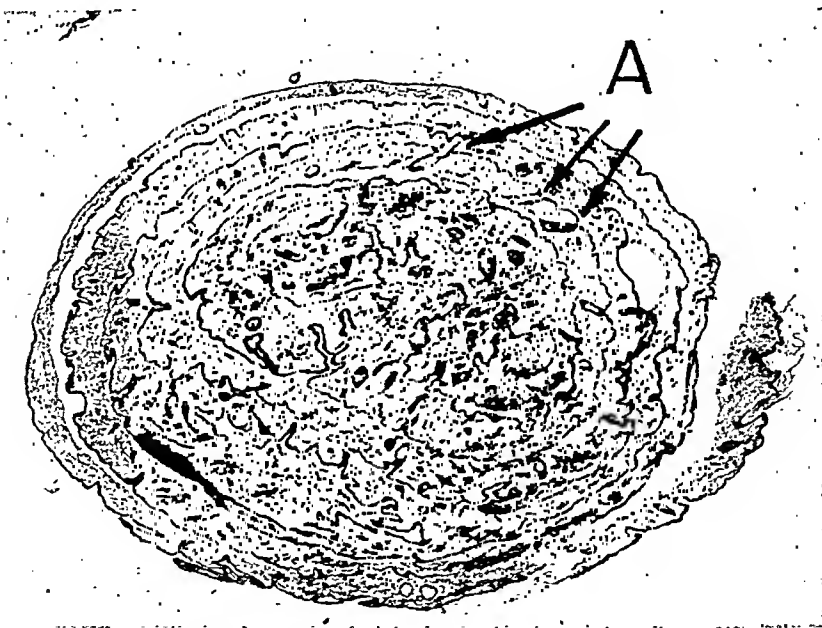


FIG. 7.—Rolled-up epidermis from Dog 3, taken at a depth of 0.010 inch. Note the numerous bisected hair follicles, some of which are seen at (A).



remnants and only traces of hemosiderin deposits. Sections of the donor area to which the unused epidermis had been regrafted showed essentially normal skin.

**Experiment 17.**—(Dog 7, female, 9.8 Kg.) *Aortic Ligation*: A cutis graft 8 x 12 cm. was taken from the chest by the split-split method (epidermis 0.020 inch, and cutis 0.020 inch additional). Marcks' copper gauges were used to measure the thickness of the grafts in this and in ensuing experiments. Sections of epidermis and cutis were similar to those in Figures 7 and 8. Three strips 1 x 12 cm. were used to ligate the

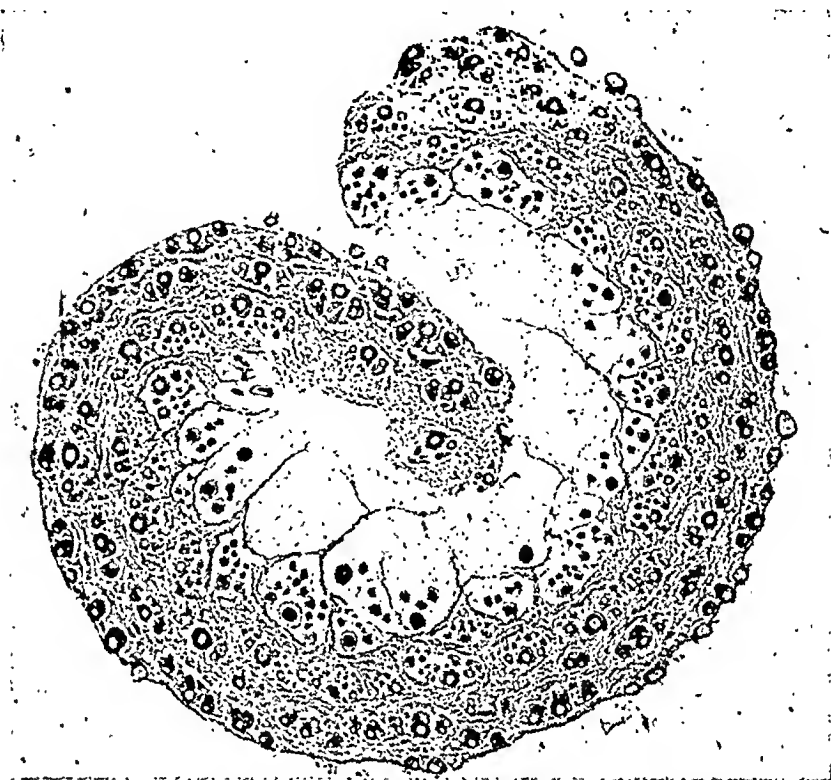


FIG. 8.—Rolled-up cutis graft from Dog 3. The epidermis was removed at a depth of 0.014 inch, and the cutis removed from the underlying bed with a scalpel. Note the large number of epithelial elements as compared to the human case seen in Figure 4.

abdominal aorta. A triple tie was used in each case and the knots were transfixed with one silk suture which did not surround the aorta. On the twelfth day the animal died of distemper. The donor area to which the epidermis had been resutured was entirely healed. All wounds were healed and clean. The aortic ligatures had atrophied and the lumen was reduced by only one-third.

**Experiment 18.**—(Dog 7) *Abdominal Wall Defect*: A 2.5 x 7.5 cm. area of oblique muscles was excised and the remainder of the cutis graft was fastened with interrupted silk sutures in place, epidermal side down, over the transversalis muscle. At necropsy, the graft was clean and was quite adherent on its lower (epidermal) surface, but not quite on its upper surface. A section of the cutis shown in Figure 9 demonstrates good fusion to the surrounding structures, but with contained epithelial elements including hair follicles. A section of the grafted donor area shows the graft viable and united with the underlying structures by a thin zone of granulation tissue. Sections of the abdominal wall showed the muscle quite adherent to the underlying internal oblique. A moderate number of hairs and hair follicles were fused with the surrounding tissue. Round cells were seen but no polymorphonuclear neutrophile collections were found.

**Experiment 19.**—(Dog 8, female, 7.7 Kg.) January 15, 1945. *Aortic Ligation*: Two strips of cutis 1 cm. wide obtained by the split-split method from the chest (epidermis 0.020 inch, and cutis 0.020 inch additional) were used for ligatures of the abdominal aorta. The knots were sutured with silk to prevent slipping but the silk

did not surround the aorta. The animal died of distemper on the 17th day. The aortic lumen was not reduced. The cutis had degenerated into a mass of sebaceous material about 12 mm. in diameter. No true pus was present. The donor areas to which the epidermis had been resutured were entirely healed.

**Experiment 20.**—(Dog 9, female) March 5, 1945. *Abdominal Wall Defect:* A cutis graft obtained by the split-split method from the upper abdomen (epidermis 0.020 inch, and cutis 0.020 inch additional) was sutured in a defect of the entire thickness of the abdominal wall below the subcutaneous tissue measuring 2.5 x 7.5 cm. Sections of a portion of the cutis showed it to be irregular in thickness with one side composed

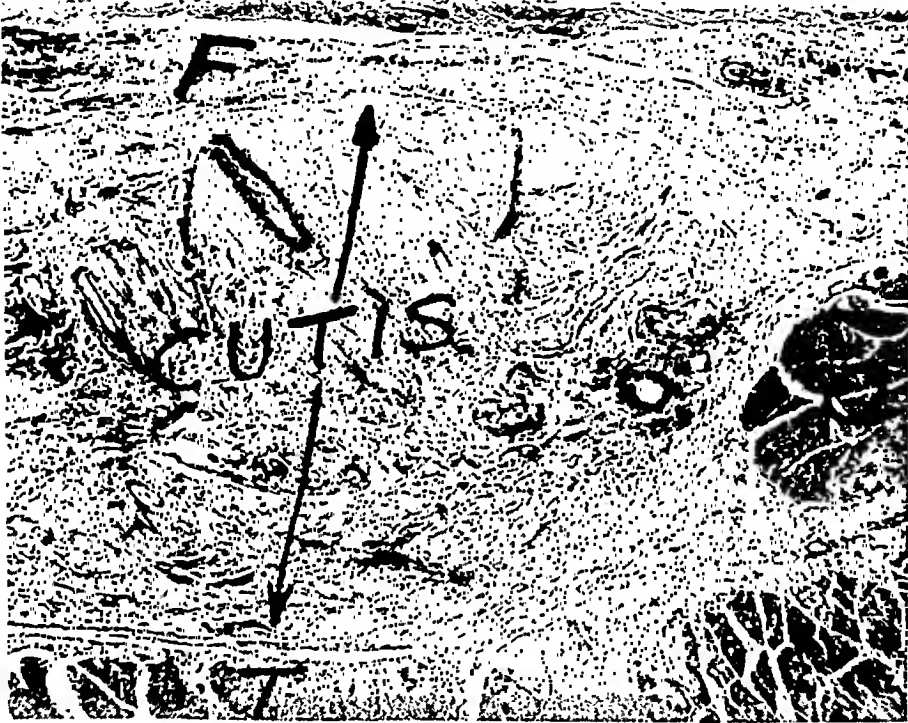


FIG. 9.—Cutis graft in place at necropsy 12 days after operation in Dog 7. A strip of cutis was obtained from a full-thickness graft of 0.040 inch by splitting it in two by the split-split method and utilizing the deeper half. An area of external and internal oblique muscles, 3 x 1 inches, was excised and the strip of cutis fastened upside down on the transversalis muscle (T). The cutis lies beneath the superficial fascia (F) and joins the oblique muscles (O) on the right. It contains epithelial elements, including hair follicles.

mainly of fat and containing practically no epithelial elements while the other side contained many hair roots and some hairs. The graft was sutured to the cut edges of the surrounding muscles with the epidermal side facing the intestines. The donor site to which the epidermis was resutured was entirely healed in one month. At the time of sacrifice on September 21, 1945 (6.5 months) the animal was in excellent condition and there was no sign of hernia. All wounds were well healed. Histologic section of the donor skin grafted area showed good epithelium with hairs and other accessory epithelial elements. A surrounding edge of second degree scar-healing showed a thin layer of epithelium with very few hairs. The graft was firm, but not as strong as the surrounding tissues and had shrunk to a size of 7.0 by 2.5 cm. Histologic section of the cutis graft scar showed many small cysts containing hairs and epithelial buds.

**Experiment 21.**—(Dog 10, female) March 12, 1945. *Abdominal Wall Defect:* This was exactly similar to the preceding experiment except that the epidermal thickness was 0.018 inch, and the cutis 0.022 inch, and the cutis was placed epidermal side out in the abdominal wall. Sections of a portion of the cutis showed it to be mainly fat. Few epithelial elements were present and these included hairs, hair roots, and one demon-

strable sudoriferous gland. The animal was found dead on April 4, 1945 (23 days) with minimal distemper. The donor site was only 50 per cent healed. The cutis graft was well healed and clean. The defect had shrunk to 3 x 6 cm. Sections showed that the graft was of poor quality containing considerable fat, a very occasional hair but no other epithelial elements. One small collection of polymorphonuclear neutrophils lay beneath the skin at the edge of the graft but superficial to it.

**Experiment 22.**—(Dog 11, female) March 21, 1945. *Diaphragmatic Defect:* A cutis graft of a thickness similar to that of the last experiment was taken from the abdomen and sutured into a full-thickness excised defect in the left diaphragm through a transthoracic approach with the epidermal side towards the chest. Sections of a portion of the cutis revealed a thin layer of muscle with fat on each side and with no epithelial elements. On July 19, 1945 (four months) the dog was well, the donor site was well healed and the wound was clean. Death occurred on August 28, 1945. Necropsy was not performed.

**Experiment 23.**—(Dog 12, female, 4.5 Kg.) March 28, 1945. *Abdominal Wall Defect:* A cutis graft of thickness similar to that in the last two experiments was taken from the upper abdomen and sutured into a whole-thickness defect of the abdominal wall musculature about 2.5 x 9 cm. Sections of the graft showed it to be very uneven in thickness. In one place it had practically no cutaneous elements, in another a great many. The graft was folded double with the epidermal layer inside facing itself. The animal was sacrificed on June 27, 1945. The donor area was entirely healed. The abdominal wound was entirely clean and healed and represented a perfect result. There was no weakness. The defect measured 3 x 9 cm. The intestines were not adherent to the underside of the graft but the omentum was slightly attached. The graft was well adherent in its upper surface. Histologic section showed a thick layer of relatively normal fibrous tissue containing very occasional hairs.

**Experiment 24.**—(Dog 13, female, 5.2 Kg.) March 29, 1945. *Diaphragmatic Defect:* A cutis graft taken from the abdomen by the split-split method (epidermis 0.014 inch, and cutis 0.026 inch additional) was sutured to a 2.5 x 4 cm. defect in the diaphragm with the epidermal side towards the chest. The animal died in four hours, and at necropsy the graft was seen to be quite intact.

**Experiment 25.**—(Dog 14, female, 6.0 Kg.) April 2, 1945. *Diaphragmatic Defect:* A graft similar to that in Experiment 24 was sutured to a diaphragmatic defect 4 x 6 cm. with the epidermal side towards the chest. The animal was sacrificed on June 27, 1945 (2.5 months). The donor site was entirely healed and the chest wound was clean. The graft was intact without weakness and was firmly attached to the lung and only partially attached to the liver. Sections of the cutis at the time of operation were similar to Figure 8 except that epithelial elements were not so widely distributed. Histologic examination of the graft at necropsy revealed an intact graft firmly adherent to the underlying lung and in places adherent to the liver. The graft contained a few hairs and hair roots and sebaceous cysts 0.5 mm. or less in diameter. No notable signs of inflammation were present. Sections of the donor site revealed an intact but thin epithelium with hairs and underlying glands.

#### RESULTS OF CULTURES

Aerobic and anaerobic cultures of the cutis obtained from the first five dogs all showed only a gram-positive anaerobic gas-forming bacillus with no spore formation or branching. In one case (Dog 3) where incidentally only a thin (0.010 inch) layer of epidermis was removed, an additional growth of *Staphylococcus aureus* was observed. At necropsy the wounds of Dogs 4 and 5 were grossly infected.

## ANALYSIS OF EXPERIMENTAL DATA

A total of 25 experiments on 14 dogs included 13 abdominal implants, five bridging of abdominal wall defects, two ligations of the common iliac artery, two ligations of the abdominal aorta, and three bridging of diaphragmatic defects.

In the series of 13 abdominal wall implants at various levels and positions, all examined at necropsy, no remnant of the graft was found in one case, granulation tissue or pus was found four times, gross hairs in two instances, gross sebaceous material in two instances, sinuses once, and apparently clean healing six times. In eight experiments histologic sections were made and all revealed epithelial elements including two in which no gross hairs were evident. In 12 instances where fusion of the graft to surrounding surfaces could be noted, fusion was present on both surfaces eight times, on the fat side but not on the epidermal side of the graft twice, and the graft was not adherent at all in two instances. Of the 13 grafts observed, only six were without some complication (pus, hair, sebaceous material, entire disappearance of the graft, *etc.*).

In the series of five bridging of abdominal wall implants, all examined at necropsy, on gross examination all showed complete absence of hair, pus, cysts, *etc.* Three grafts were adherent on both surfaces and one on the epidermal surface only. Histologically, hair was present four times and absent once.

In the series of two common iliac ligations, in one there was no remnant of the graft and no occlusion of the artery, and in the other the artery was occluded, but a mass of sebaceous material was present.

In the series of two aortic ligations, in neither case was the aorta occluded. In one the graft had disappeared, in the other a sebaceous mass was present.

In the series of three diaphragmatic defects of two animals examined at necropsy no gross evidence of abnormal healing was observed (one animal, Experiment 24, died after only four hours; the other, Experiment 25, was sacrificed after 2.5 months). The graft was adherent mainly on its epidermal surface in Experiment 25, and sections in this case revealed hairs and sebaceous cysts.

## NOTE ON THE USE OF WHOLE SKIN AS A SUBSTITUTE FOR FASCIA (AND FOR CUTIS)

In the January, 1945, issue of the British Journal of Surgery an article by Mair of Aberdeen, Scotland, appeared on the use of whole skin grafts as buried patches for the repair of hernia. This author reports the use of this method in 88 herniae, and studied the results of whole skin implants in rabbits. This same author has another article in a recent issue of the American Journal of Surgery. Despite the excellent results reported with this method, it would appear to be more risky than the use of cutis, but these articles deserve reading. It would seem that while one layer of cutis might be weaker than one layer of whole skin, two layers of cutis would

be stronger and still not have as many epithelial elements combined as the single layer of skin.

#### SUMMARY

A cutis graft reinforcement patch was used in the surgical repair of 11 cases of large ventral or incisional herniae. These herniae were in most instances chosen for this type of repair because of their large size and associated obesity of the patient. Seven cases were specifically selected from a large number of ward patients because of the magnitude of the hernia.

In all cases the fascial layers were closed with silk sutures and the cutis acted only as a supportive patch. The cutis was obtained by four methods: (1) Dermatome flap; (2) Scola double graft; (3) split-split; and (4) from tissue removed from the region of the hernia by lipectomy. In all cases, except when the fourth method rendered it unnecessary, the donor area was again covered with the removed epidermis.

The results of the operation were completely satisfactory in all but one instance (Case 10). In this instance some diastasis of the upper end of the wound recurred. It is impossible to state, however, that the basic silk repair, often by the Mayo technic with imbrocation, might not have been equally satisfactory and that the cutis graft was superfluous.

The chief objections to use of cutis grafts have been met in these clinical cases as follows: (1) Infection with drainage occurred in only one wound, and in that instance was associated with finding a different organism from that cultured from the cutis at the time of operation. (2) Cyst formation from persistent epithelial elements has to date caused no obvious trouble in any case. (3) Increased operating time has been largely obviated by use of the split-split method.

Variations in the technic whereby single and double layers of cutis were used; whereby in different cases the cutis was placed epidermal side down (seven instances) and epidermal side up (one instance); whereby the thickness of the removed epidermis and of the cutis itself was varied, all seemed to have no effect on the results.

While the results of the human cases were in general quite satisfactory, the animal experiments were accompanied by a high incidence of complications. In all cases but one of the 14 where sections of the buried graft were taken at necropsy, epithelial elements were present. Pus, hair, sebaceous material, or sinuses were observed in 18 out of 24 experiments (75 per cent) in which the graft was observed at necropsy. In four other instances no epithelial remnant of the graft was found and in the two remaining cases the intact graft was observed. Most of these complications followed the insertion of the cutis as abdominal implants or its use as arterial ligatures. The experiments where the graft was actually sutured under tension to close muscular defects in the abdominal wall or diaphragm were much better, with no gross complications of healing being observed in six such experiments.

Ligations of the abdominal aorta and common iliac arteries were not successful with cutis strips. Either the artery was not occluded or the cutis

degenerated into sebaceous material. The reestablishment of continuity of the arterial lumen is possibly attributable to the elasticity of the cutis.

The difference between the human and animal experiments would seem to be a quantitative rather than a qualitative one. It is impossible to remove all of the epithelial elements from the cutis without excising such a thick layer of epidermis that no dermis is left behind. It was one of the initial hopes of this investigation that with the modern precise methods of taking grafts at known depths the optimum thickness of cutis and of removed epidermis might be ascertained. Actually, it seems to make little difference because once the superficial epidermis is shaved off—and this can be done by a very shallow setting of the dermatome (0.008 inch, or even less)—the epithelial elements in the underlying cutis penetrate deeply. It is true that quantitatively the deeper one removes the epidermis the less the remaining cutaneous remnants, but also the less the remaining cutis. This quantitative difference is especially noticeable in the animal experiments where a large amount of epithelial material in the cutis (estimated histologically in area as 50 times as much, or more, in a section of cutis of equal size) is far greater than in a human cutis graft.

#### CONCLUSIONS

1. Quantitative studies on cutis grafts cut at various thicknesses indicate that superficial removal of the epidermis need be no more than 0.008 inch.

2. A relatively nonhairy donor site is desirable to avoid as much as possible the inclusion of hair follicles and attached glands. The danger of such an inclusion is essentially quantitative rather than qualitative, but is always to be considered. With adequate skin preparation infection does not seem to be a major menace.

3. The split-split method is the most useful technic for obtaining cutis grafts.

4. It seems to make little difference whether the cutis is used with the epidermal side up or down, or whether it is inserted in single or double sheets.

5. Cutis grafts should be applied under tension and when used in the surgical treatment of hernia should be fastened as a supporting patch over the suture line of an otherwise adequate repair of the fascial layers with nonabsorbable sutures.

6. Cutis grafts as used in these experiments are not suitable for ligation of major arteries.

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# THE PATHOGENESIS OF LOCALIZED FIBROUS LESIONS IN THE METAPHYSES OF LONG BONES

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LOCALIZED BENIGN FIBROUS LESIONS which are situated in the metaphyses of long bones have been described under a variety of diagnoses. The diverse interpretations accorded examples of this disorder have been due mainly to overemphasis on various secondary characters prominent in the natural course of the condition. Phélip,<sup>1</sup> and Burman and Sinberg,<sup>2</sup> among other described typical examples of this fibrous lesion as solitary xanthoma, not recognizing that the lipoid accumulation was a secondary manifestation. Superficial resemblance of the fibrous lesions to solitary bone cyst and to benign giant cell tumor led Geschickter and Copeland<sup>3</sup> to interpret them as variants of these disorders. Phemister,<sup>4</sup> in 1929, reported on the pathologic characteristics of a group of localized, nonsuppurative lesions of bone which he termed fibrous osteomyelitis. Included in his cases were instances of the lesion now identified as osteoid osteoma as well as examples of metaphyseal fibrous defects. In 1942, Jaffe and Lichtenstein<sup>5</sup> demonstrated the various stages in development of solitary fibrous lesions of bone, interpreted them as benign tumors formed from matured marrow connective tissue and applied the name non-osteogenic fibroma of bone.

The purpose of this presentation is to demonstrate the clinical, roentgenologic and pathologic findings in the various stages of the lesion's development and regression. Attention is brought to the frequency with which evidence of concomitant disturbances in epiphyseal cartilage and in bone are observed. The significance of this observation in the pathogenesis of the fibrous metaphyseal lesion is discussed. The basis for this report is the study of 45 patients in whom were identified 51 lesions of the type under discussion. Lesions were found in more than one bone in five patients. There are 28 males and 17 females in the group. That the disorder has its inception during the period of longitudinal growth of bone is indicated by the fact that all except seven patients were children at the time of recognition of the abnormality. The defects in the bones of adult patients showed roentgenographic evidence indicative of long duration of the disorder. The youngest patient who had a metaphyseal defect was six years, and the oldest was 40 years at the time diagnosis was made.

In all these cases the lesion was in the long bones of the lower extremities. Jaffe and Lichtenstein found in ten cases one with localization in the distal end of the ulna. In the present group the lesions are distributed in the skeleton as follows: Thirty-two in the distal portion of the femur; 11 in the proximal portion of the tibia; five in the distal metaphysis of the tibia; and



two in the distal third of the fibula. All of them are situated in the metaphysis or adjacent shaft where they are usually eccentrically placed. The defect often abuts on the cortex or occupies a portion of it.

A typical example of a metaphyseal fibrous defect, illustrating its eccentric location in the distal end of the femur, is seen in the following case:

**Case 1.**—E. S., male, age 17, had recurrent attacks of pain in the left knee for 1.5 years. Examination showed evidence of fluid within the knee joint and localized tenderness mesially over the distal end of the femur. Roentgenograms (Fig. 1) show a zone



FIG. 1.—Case 1: Roentgenograms show area of reduced density mesially in the metaphysis of femur.

of reduced density mesially in the metaphysis which occupies a portion of the cortex. It is demarcated from surrounding bone by a narrow scalloped sclerotic margin. Bloc excision of this focus was done. The specimen (Fig. 2) presented as a fibrous mass with brownish discoloration, occupying a smooth-walled cavity in the bone. The outer cover of the cavity is periosteum which blends into the fibrous tissue of the focus. A slight amount of periosteal new bone is present here. Microscopic examination (Fig. 3) discloses whorls and strands of fibrous tissue with small areas of recent hemorrhage and blood pigment deposition. Scattered multinucleated cells are found; also, in some areas, lipid-containing macrophages are observed. The bony wall shows evidence of bone absorption in some regions; in others, bone apposition is apparent. There is no ossification within the fibrous mass. The zone of reactive bone about the focus is narrow and the surrounding marrow is normal. The patient's symptoms were relieved by operation, and he is well, four years later.

In five patients there were lesions in more than one bone. Two had defects in the tibia and femur of the same extremity. One had lesions in both femora and in one tibia. Both tibiae were involved in one case and both femora in another. Although the lesion is unilocular there are occasionally seen smaller separate adjacent foci.

Involvement of more than one bone is illustrated in the following two cases:

**Case 2.**—C. C., female, age ten, had pain, tenderness, and slight swelling over the left tibial tubercle for two weeks. A clinical diagnosis of Osgood-Schlatter's disease was made. Roentgenograms (Fig. 4) show an area of reduced density with marginal sclerosis in the distal portion of each femur and in the proximal end of the right tibia. The one in the right tibia is close to the epiphyseal disk. In the right femur the lesion is in the shaft, further from the growth disk, and has greater sclerosis about it. The lateral



FIG. 2.—Case 1.—Photograph of bloc shows defect in cortex filled with fibrous tissue.

cortex of the left femoral metaphysis is the site of a smaller lesion. The left tibial tubercle is of irregular density. The symptoms in this patient were connected with changes in the tibial tubercle. The metaphyseal foci caused no pain and no treatment was given them.

**Case 3.**—N. W., female, age 11, had tuberculosis of the right hip for which arthrodesis was done at the age of four years. There were no symptoms referable to the knees. Roentgenograms of both knees were made for examination of the epiphyseal cartilage disks because of limb length inequality. These roentgenograms (Fig. 5) disclose an area of rarefaction in the proximal metaphysis of each tibia. That in the left tibia borders on the epiphyseal cartilage. In the right tibia a similar area is situated further from the epiphyseal line and encroaches upon the medial cortex.

The symptoms produced by this defect are usually mild. In several instances its presence was discovered in roentgenograms made because of recent injury to the limb. Pain, when present, is mild, intermittent, and often referred to the neighboring joint. Local tenderness over the involved area is present when the lesion lies in, or close to, the cortex. Symptoms and

physical findings of epiphyseal disturbances led to the discovery of the associated metaphyseal disorder in 14 patients.

#### ROENTGENOGRAPHIC APPEARANCE

The roentgenographic appearance of the metaphyseal defect is distinctive, and in conjunction with clinical findings diagnosis can be made with considerable certainty. Early, there is a limited area of reduced density in the meta-

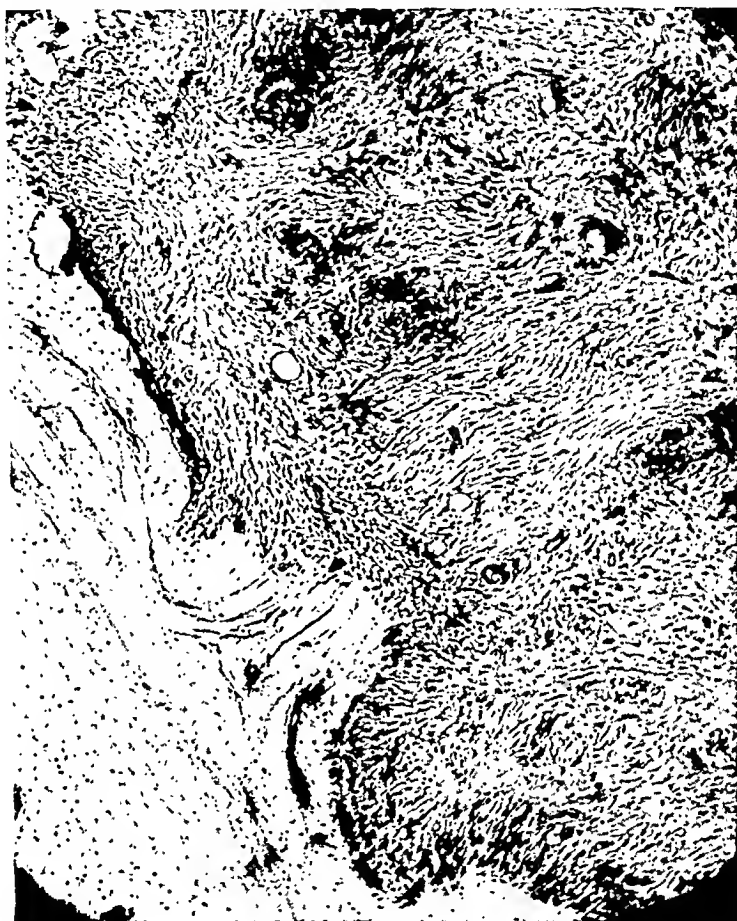


FIG. 3.—Case 1: Photomicrograph shows whorls and strands of fibrous tissue with scattered multinucleated cells.

physis close to the epiphyseal disc. Later, the area is apt to be elongated in the direction of the axis of the bone and show sharp demarcation from surrounding normal bone by a narrow shell of bone sclerosis. Irregularly scalloped margins give the appearance of loculation on the roentgenograms. Through longitudinal growth of the bone the defect comes to lie further from the epiphyseal cartilage. Also, in the process of tubulation of the metaphysis the defect may eventually occupy a part of the cortex of the bone. In this case periosteal reaction may produce the shadow of overlying periosteal new bone. In lesions long present there may be roentgenographic evidence of progressive ossification at the periphery, with resulting marginal sclerosis several millimeters in width. Sometimes dense ossification may fill out part or all of the area, leaving a zone of increased density in the roentgenogram.

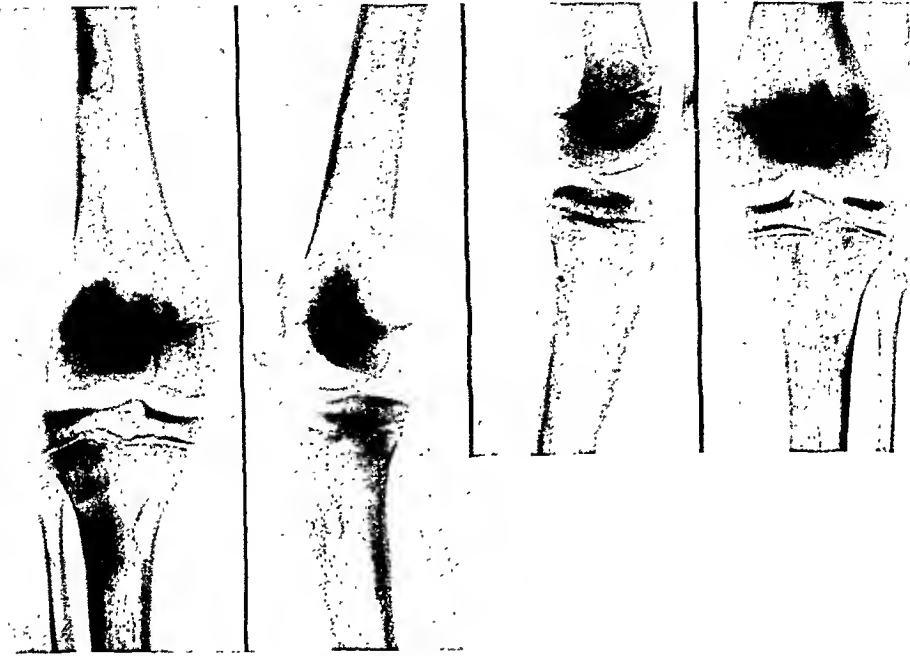


FIG. 4.—Case 2: Roentgenograms show an area of reduced density with marginal sclerosis in the right femoral as well as tibial metaphysis. In the left femur a smaller area lies in the lateral cortex.

#### PATHOLOGY

Surgical removal of the lesion was done by curetting or by bloc excision in 17 of the patients. This material afforded means for study of the histologic nature of the process at various stages.

The pathologic appearance, like the roentgenographic, varies somewhat

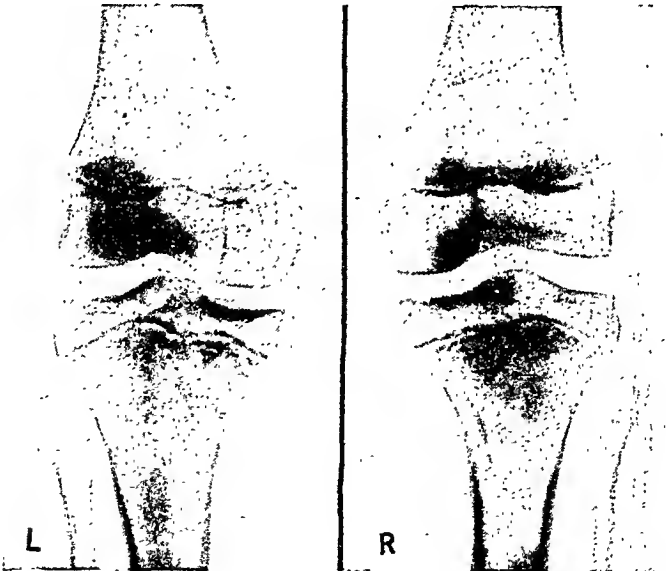


FIG. 5.—Case 3: Roentgenograms show areas of reduced density in both tibial metaphyses. That in the left tibia borders on the shadow of epiphyseal cartilage. In the right tibia it encroaches upon the shadow of the mesial cortex.

METAPHYSEAL FIBROUS DEFECTS



FIG. 6.—Case 4: Roentgenograms show ovoid area of reduced density which expands shaft of fibula.

with the age and activity of the lesion, and different areas in the same focus may demonstrate a variety of pathologic findings. The basis of the lesion in all stages is a fibrous connective tissue which occupies a smooth-walled, some-



FIG. 7.—Case 5: Roentgenograms show large area of reduced density in distal metaphysis of tibia. The shadow of an oblique fracture is visible in lateral view.

times partially loculated, cavity in the bone. The bony wall may show evidence of absorption by the connective tissue, or, in areas, there may be bone apposition. Beyond the narrow zone of hypertrophied wall the



FIG. 8.—Case 6: Roentgenograms show shadow of tibial tubercle irregular in form and density. In adjacent metaphysis there is oval area of reduced density.

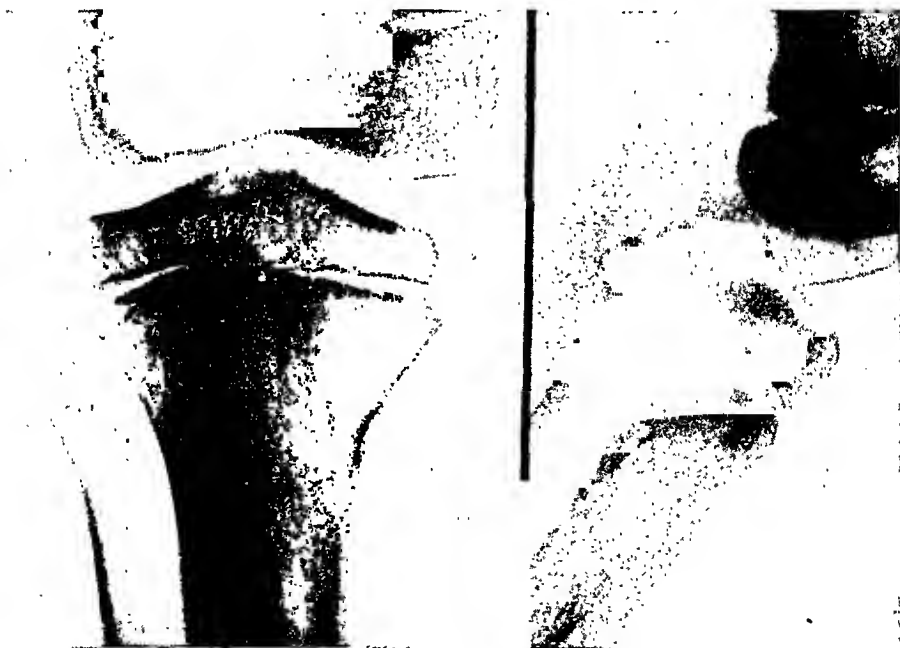


FIG. 9.—Case 7: Roentgenograms show area of reduced density in proximal metaphysis of tibia near growth disk.

marrow is normal. The recently formed focus shows a relatively cellular fibrous tissue with scattered multinucleated cells while in what appears to be a somewhat older lesion the fibrous tissue is arranged in strands and whorls. Numerous areas of recent hemorrhage and old blood pigment are seen.

Multinucleated cells may be more numerous than in the early stage. Lymphoblasts are found scattered through the fibrous tissue. Lipoid-filled macrophages are often present in focal collections or diffusely scattered through defects where roentgenographic evidence indicates a lesion of long duration. The lipoid deposition is evidence of chronicity and is not a primary feature of the disorder.

Characteristic roentgenographic and pathologic findings are illustrated in the following two cases. These sizable lesions, situated about the ankle, show bone reaction around them—indicative of relatively long existence:

**Case 4.**—M. G., age ten, female, had slight pain over lateral side of right ankle for three weeks. Examination revealed minimal tenderness over the distal end of fibula. Roentgenograms (Fig. 6) show an ovoid area of reduced density in the fibula 2 cm. proximal to the growth disk. This slightly expands the fibular shaft while the limits of the lesion are demarcated by a narrow shell of sclerosis. Surgical removal by curetting was done. Histologic examination shows moderately cellular fibrous tissue arranged in whorls and strands, and scattered with numerous multinucleated cells. Roentgenograms, ten weeks after the operation, showed repair of the defect.

**Case 5.**—L. G., male, age ten, had no symptoms referable to the left leg until he sustained a fracture of the tibia following mild trauma. Roentgenograms (Fig. 7) at this time disclosed a 2 x 2 x 4-cm. area of rarefaction in the tibia, 2 cm. from the distal epiphyseal disk. This has its longer diameter in the axis of the shaft, which it expands slightly. The irregular shadow of a narrow zone of bone sclerosis circumscribes the area and irregular trabeculation gives the appearance of multiloculation. An oblique fracture through the lesion is seen in the lateral view. Curetting resulted in complete healing. Microscopic examination shows typical fibrous tissue with moderate numbers of multinucleated cells.

#### THE RELATIONSHIP BETWEEN METAPHYSEAL DEFECTS AND DISTURBANCES IN EPIPHYSEAL BONE AND CARTILAGE

Disturbances of epiphyseal bone and cartilage were found in conjunction with metaphyseal defects in 14 of 45 patients. In fact, the symptoms of joint derangement led to roentgenologic examination, which disclosed the metaphyseal lesion. Osteochondritis of the tibial tubercle, Osgood-Schlatter's disease, was the most frequent associated epiphyseal disturbance being found in eight patients, who also had metaphyseal lesions. These patients complained of painful knee and had tenderness to pressure over the tibial tubercle. Their roentgenograms show irregular form and density of the epiphyseal bone of the tubercle and irregularly reduced density in the adjacent metaphyseal bone.

The following three cases demonstrate this association of metaphyseal defects with disturbance of epiphyseal bone:

**Case 6.**—J. R., male, age 12, had pain about the left knee for two months. There was tenderness and swelling at the tibial tubercle. Roentgenograms (Fig. 8) show irregularity in density and form in the shadow of the tibial tubercle. In addition, there is in the metaphysis of the tibia, 1 cm. distal to the tubercle, an oval area of reduced density with sclerotic margins.

In the next case excision of a metaphyseal lesion connected with Osgood-Schlatter's disease gave opportunity for histologic confirmation of its identity.

Case 7.—A. C., age ten, had pain and tenderness at the left tibial tubercle for four months. The roentgenograms (Fig. 9) show a zone of reduced density in the tibial metaphysis 1.5 cm. from the growth disk. Excision of the area was done. The histologic preparation (Fig. 10) shows fibrous tissue with multinucleated cells identical with that seen in the other cases.



FIG. 10.—Case 7: Photomicrograph shows fibrous tissue with occasional multinucleated cells.

Another case shows long persistence of the metaphyseal lesion which together with Osgood-Schlatter's disease arose from a disturbance at the growing epiphysis.

Case 8.—J. Y., male, age 13, had painful and tender tibial tubercles for two years. Roentgenograms showed irregular density and form of both tubercles and, in addition, that of the left tibia (Fig. 11a) discloses small areas of reduced density in the adjacent metaphysis. Four years later a roentgenogram (Fig. 11b) shows a rounded zone of reduced density with sclerotic margins.

Metaphyseal foci associated with Osgood-Schlatter's disease were observed in both the distal femur and proximal tibia in two patients and, in three, foci were visible in the femur but not in the tibia. The multiplicity of lesions in metaphyses found associated with an epiphyseal alteration must mean that the underlying disturbance is more extensive than has been recognized.

Osteochondritis dissecans of the femoral condyle was found in connection



# METAPHYSEAL FIBROUS DEFECTS

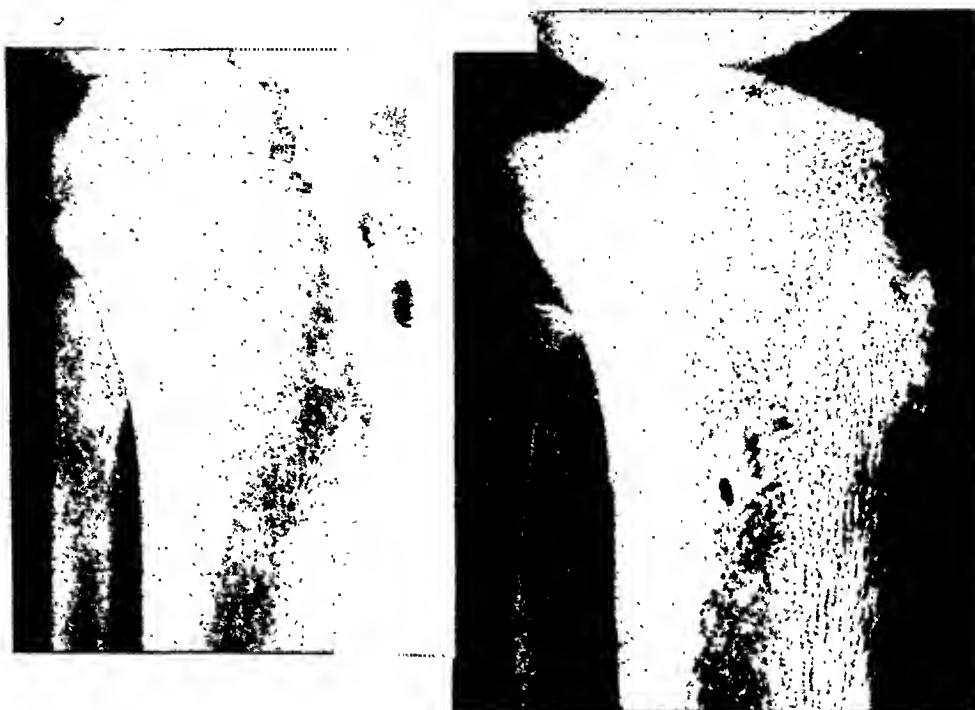


FIG. 11.—Case 8: Roentgenogram A shows small areas of reduced density in proximal tibial metaphysis adjacent to tibial tubercle which is irregular in density and form. B. Four years later, shows rounded zone of reduced density with sclerotic margins.

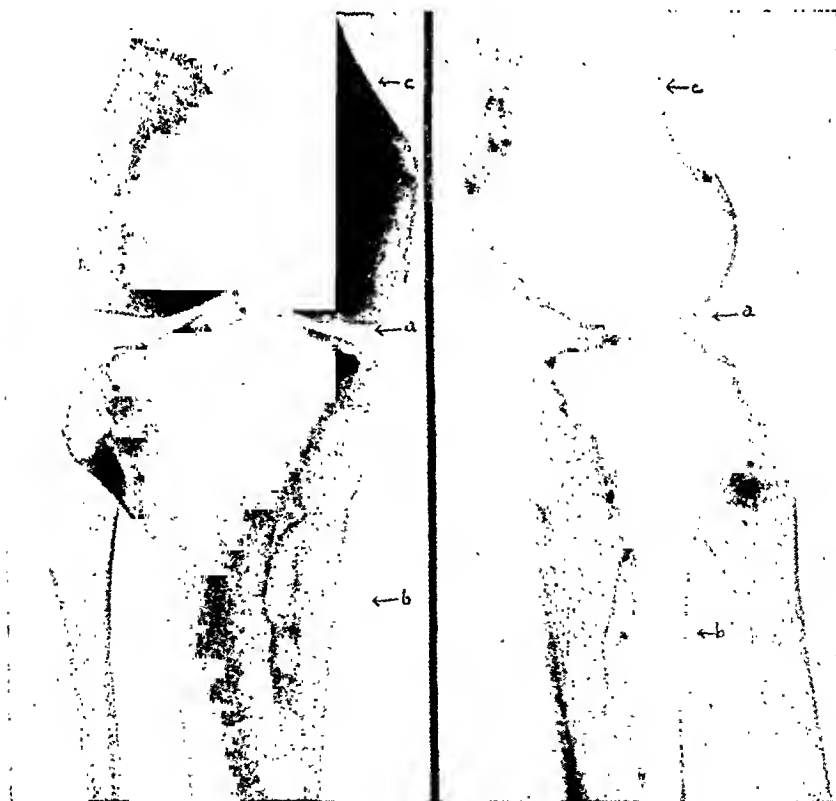


FIG. 12.—Case 9: Roentgenograms show shadow of wedge of bone of greater density separated from medial condyle (a); large area of reduced density with sclerotic margins in proximal tibia (b); the shadow of a smaller area of reduced density is visible medially in femur (c).

with metaphyseal foci in four patients. An area of demarcated rarefaction was observed in the distal femoral metaphyses in all these patients. The following patient had also a metaphyseal defect in the proximal tibia.

**Case 9.**—G. O., male, age 17, had, for nine years, noted intermittent aching in the left knee. For the past four months there had been attacks of painful catching of the knee in flexion. Roentgenograms (Fig. 12) disclose, in addition to the shadow of a separated wedge of articular bone in the lateral portion of the medial femoral condyle, two circumscribed areas of reduced density in the metaphyses on either side of the joint.



FIG. 13.—Case 9: Photomicrograph shows fibrous tissue with multinucleated cells and lipid filled macrophages.

The one in the tibia is the larger and has more sclerosis about it. In the femoral metaphysis the area is smaller and has little evidence of surrounding bone reaction. At operation, the osteochondritic fragment was excised and the metaphyseal focus in the tibia was curetted. The material within the bone cavity was yellowish fibrous tissue. Microscopically, it consists of fibrous strands with multinucleated cells and clusters of lipid-containing macrophages (Fig. 13). Relief of symptoms followed operation. Roentgenographic examination 18 months later shows repair of the tibial defect and healing of the undisturbed lesion in the femoral metaphysis.

Osteochondritis of the patella was present in two patients who had metaphyseal defects in the distal femoral metaphysis. Disturbance of growth from the epiphyseal cartilages about the knee, of unknown cause, was associated with a metaphyseal defect in the femoral metaphysis in one case.

THE NATURAL COURSE OF THE DISORDER—TREATMENT

It is obvious that the metaphyseal defect found commonly in childhood, and but rarely in adult life, must undergo spontaneous healing. Several modes of obliteration of the lesion have been observed. In the first place, a defect found in the metaphysis of a young child may heal rapidly by reparative ossification, or, if it is located near the margin of the metaphysis, longitudinal growth and tubulation of the bone cause it to be displaced to the outer surface of the bone and obliterated. If early repair does not occur and the lesion is so

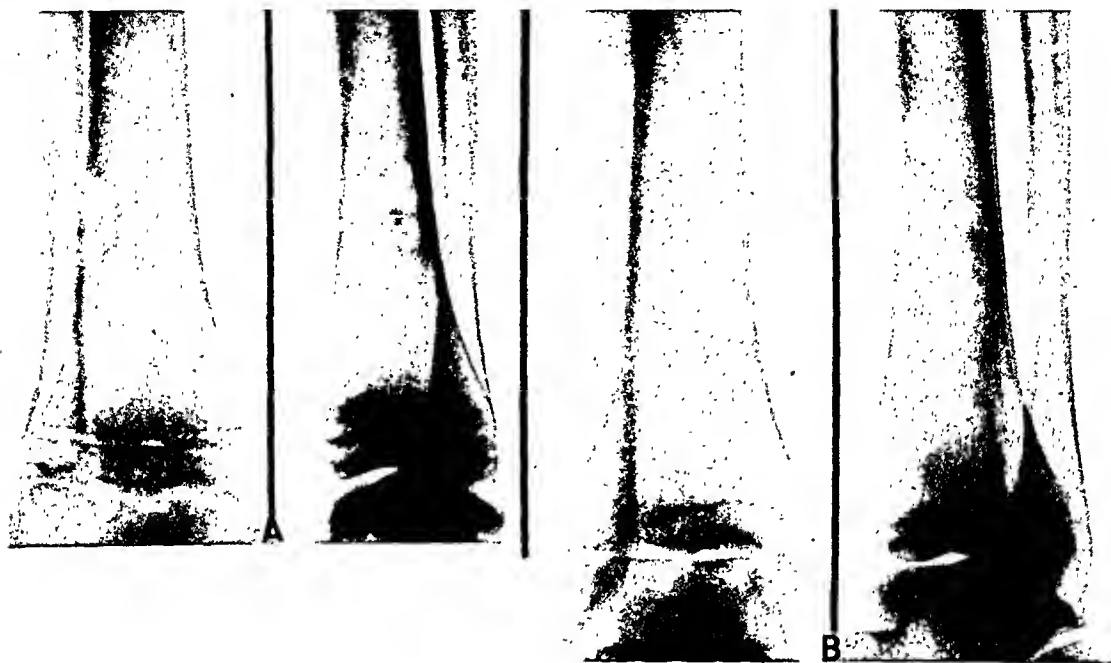


FIG. 14.—Roentgenograms show:

- A. Shadow of area of reduced density with sclerotic margins.
- B. Four years later, evidence of filling in by bone of normal density.

situated that it is not carried to the outer surface, it usually becomes encapsulated by a thin sclerotic wall. Such a focus may then undergo gradual obliteration by ossification from its walls. Sometimes this will result in restitution of normal architecture of the region; sometimes a localized hypertrophy of bone will remain to mark the site.

An illustration of spontaneous healing is presented in the roentgenograms (Fig. 14a) of a symptomless fibrous defect in the distal end of the tibia. During four years there was gradual filling-in of the area by normal bone to the degree noted in Figure 14b.

Occasionally the encapsulated area shows no tendency to repair and persists into adult years. Rarely may the fibrous elements of the focus continue to destroy bone and produce a gradually expanding lesion. Such was the situation in the following patient.

Case 10.—H. D., male, age 19, had noted a tender swelling over the right tibia for one month. Roentgenograms (Fig. 15) demonstrate a fairly large irregular area of reduced density with sclerotic margins. The proximal portion of this region

shows increased density, indicative of bony repair. The distal and mesial regions show little evidence of filling-in by bone. The shadow of mesial cortex bulges and is thinned over its apex. Partial osteotomy was done and the defect filled with bone chips. The histologic appearance varies somewhat in the different regions. In the more sclerotic zone the fibrous tissue is relatively less cellular and more collagenous and contains lipoid macrophage collections. Tissue from the area of rarefaction near the medial cortex is more cellular with numerous multinucleated cells and foci of lymphoblasts. The patient was relieved of symptoms by the operation, and healing resulted.



FIG. 15.—Case 10: Roentgenograms demonstrate a large area uneven in density and form in proximal portion of tibia. Proximally, there is increased density indicative of repair.

Since the lesion is usually not associated with much disability and since spontaneous repair is the rule, surgical excision is not frequently indicated. Also, the clinical and roentgenographic findings are so characteristic that confusion with solitary cysts, giant cell tumor, sarcoma, or other bone lesions requiring excision usually need not occur. In instances where eradication of the focus was indicated by persistent pain, bloc excision or curettage resulted in complete healing and no recurrences have been noted.

DISCUSSION.—Since localized fibrous lesions have their inception exclusively in childhood, and since they are always located close to the growing end of the bone, it is logical to attribute their origin to some disorder at the region of enchondral bone growth. A relation to bone growth is indicated, also, by the occurrence of the lesions in proximity to the major growth cartilages in proportion to their relative growth activity.

The association of the metaphyseal fibrous pockets with disorders of epiphyseal bone and cartilage occurs too frequently to be a mere coincidence. There is evidence that the alterations observed in the roentgenograms of the

osteochondroses do not necessarily represent the real extent of involvement. For example, in osteochondrosis of the tibial tubercle alteration of metaphyseal bone is not infrequently observed in roentgenograms; in fact, changes sufficient to produce epiphyseal separation following slight trauma have been observed.

In the cases of osteochondritis dissecans the initial epiphyseal involvement may be much more extensive than is suggested by the final separation of the necrotic fragment of bone and cartilage. Indeed, the early changes in osteochondrosis or osteochondritis are probably a local manifestation of a more general aberration in enchondral growth. Hence, Osgood-Schlatter's disorder and Legg-Perthe's disease are frequently bilateral. It is reasonable to assume that when alterations of bone occur in the secondary ossification centers, similar changes may also occur at the zone of enchondral ossification of the epiphyseal disk. The finding of metaphyseal lesions in two or more bones of the same patient seems significant in this regard.

Osteochondrosis of the capital epiphysis of the femur (Legg-Perthe's disease) is one of the most frequently observed examples of epiphyseal disorder. If the fibrous lesions have any association with such epiphyseal changes, it might be expected that they would be found commonly in the proximal portion of the femur. Such is not the case, however. It is true that some alteration of enchondral ossification at this epiphyseal disk does occur since the usual outcome is a shortened, broadened femoral neck. Juxta-epiphyseal rarefaction in the proximal femoral metaphysis may be seen in roentgenograms at certain stages of this disorder, but this usually disappears early. It is to be noted that the rate of longitudinal growth at the proximal end of the femur is slow; therefore, if a metaphyseal defect were present, it would remain close to the epiphysis and probably heal.

Except for Legg-Perthe's disease the incidence of fibrous defects in various parts of the skeleton corresponds well to the localization of epiphyseal disorders. Both are most common about the knee, that is, in the weight-bearing bones of the lower extremity. The upper extremity bones are uncommon sites for either epiphyseal or metaphyseal defects.

Objection may be raised to the assumption that all the cases described represent the same type of lesion since tissue examination was not done in each instance. However, the histologic findings in 14 cases do represent various stages of the disorder, and all show fundamentally the same pathologic characteristics. Since the clinical and roentgenologic manifestations are similar throughout the series, there seems to be no reason for not considering them all examples of the same disorder.

#### ETIOLOGY

The primary etiology of the metaphyseal fibrous defects is as obscure as that of the primary epiphyseal osteochondroses. In none of the cases has there been evidence of bacterial infection, or of any general disease such as neurofibromatosis, lipoid storage disease, or other defect which might have direct etiologic bearing. Jaffe and Lichtenstein hold the metaphyseal lesion

which they term nonosteogenic fibroma of bone to be a benign tumor of marrow connective tissue. The view that it is a tumor, with the usual clinical implication, is not supported by our study. While no clue as to the primary causation of the disturbance is available, the association with demonstrable epiphyseal disorder is considered significant. This association is further borne out by a similarity in course which suggests that the fibrous lesion of the metaphysis also may follow vascular derangement.

#### SUMMARY

1. A study of 45 patients who had metaphyseal fibrous defects in the bones of the lower extremities is reported, and pathologic findings in 17 cases are described.
2. Concomitant epiphyseal disorders were observed in 14 cases. The probable significance of this relationship is pointed out.
3. Spontaneous healing of the fibrous metaphyseal lesions was usual. In few cases was surgical eradication necessary for relief of pain.
4. There is evidence that the disturbance which results in metaphyseal and/or epiphyseal disorders is not as localized as is usually thought.
5. Although the primary etiologic factors are unknown, there is sufficient similarity to the course of recognized epiphyseal disturbances to suggest a common pathogenesis.

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# BILATERAL ADRENALECTOMY IN PROSTATIC CANCER

## CLINICAL FEATURES AND URINARY EXCRETION OF 17-KETOSTEROIDS AND ESTROGEN\*

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METHODS which inhibit androgenic production or action either by orchiectomy or estrogen administration have been found to reduce the activity of cancer of the prostate in many instances<sup>1, 2</sup>; in other cases these measures fail to control the disease, either immediately or more often following a remission of some months or years. It has been postulated that the production of androgen by organs other than the testes is responsible for the activity of prostatic cancer where control of the testicular androgens has resulted in failure, either immediate or delayed.

There is considerable evidence that the adrenal cortex of several species, including man, elaborates androgens in amounts of physiologic significance. Androgen-producing tumors occurring in the adrenal cortex, especially of women and little boys, often lead to masculinization—regression of the pathologic status occurring after extirpation of the tumor. The X-zone of Price<sup>3</sup> occurring in the adrenal cortex of young rats induces pubertal changes in the prostate of males castrated early in life. In guinea-pigs which had been castrated shortly after birth, tumors of the adrenal cortex developed after many months, inducing maturity in the secondary sex organs<sup>4</sup>; Wooley and Little<sup>5</sup> observed that early orchiectomy in male mice of the strain JAX ce produced adrenal tumors with masculinization in some and estrogenic effects in the accessory sex organs of others. After orchiectomy for prostatic cancer there is a fall in the urinary excretion of total neutral, as well as *beta*, 17-ketosteroids followed by a considerable increase for prolonged periods.<sup>19</sup> This preliminary fall appears to be dependent upon the removal of the gonads and is not an indifferent effect of the operative procedure. Further, it seems likely that the increase is induced through the adrenal cortex by way of the pituitary gland.

The study of prostatic cancer has been hampered by the rarity of this disease in laboratory animals. Adrenocarcinoma of the prostate gland has not been produced in the laboratory; the implantation of 1:2 benzpyrene in the prostate of rats<sup>6</sup> has resulted in the production of squamous cell carcinoma, a type which is rare in man. Prostatic cancer occasionally occurs spontaneously in the dog. Schlotthauer and Millar<sup>7</sup> observed it in three dogs, and Krause,<sup>8</sup> and Roth,<sup>9</sup> in single cases. Engle and Stout<sup>10</sup> discovered prostatic cancer in a

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monkey at autopsy. We have observed adenocarcinoma of the prostate twice in a series of 637 dogs whose prostate glands were examined cytologically in this laboratory. The disease has never been recognized in a living laboratory animal so that functional observations have not been feasible in the lower forms.

In experimental animals the adrenal glands have been removed with preservation of life and good health for many months by means of substitution therapy. Because of the hypothesis that adrenal androgens were stimulating the growth of prostatic cancer and since the natural life expectancy clearly was short in the cases to be considered in this paper, the adrenal glands were removed in two stages from four men with rapidly growing metastatic cancer of the prostate, all having had the previous benefit of orchiectomy. These men survived 1.5, 1.5, 11 and 116 days after bilateral adrenalectomy, and are the basis of the present communication. In this paper it will be demonstrated that there is an additional factor in some prostatic cancers, namely, androgen-independence.

Since postoperative adrenal failure occasionally occurs following less drastic adrenal surgery, the methods by which survival occurs after complete adrenalectomy are presented in detail. Complete adrenalectomy in man, with survival, has not been described previously.

#### CASE REPORTS

Case 1.—A. E. D. (history No. 266,424), a physician, age 58, was first seen on July 9, 1941, complaining of sciatica of six months' duration. The prostate gland was hard, nodular, fixed and very large. A roentgenogram showed widespread osteoplastic metastases in the pelvis. The serum acid phosphatase was 7.5 units\* and alkaline phosphatase 36 units.

A diagnosis of cancer of the prostate was made, and bilateral orchiectomy was accordingly carried out on July 17, 1941. Relief of pain occurred within six days, and shortly thereafter the patient resumed the practice of his profession. Seven months after orchiectomy, acid and alkaline phosphatase values were 4.5 and 6 units respectively. One month later a reactivation of the disease occurred, judging by a rise of alkaline phosphatase, which was progressive. In June, 1942, pain reappeared and became steadily worse, requiring injections of morphine. On January 25, 1943, the left adrenal gland was removed through a loin incision; its weight was 5.4 Gm., and it was normal on cytologic study. The blood pressure was 120/84. The serum sodium and potassium were normal. On February 12, 1943, the right adrenal was removed under ethylene anesthesia; it was normal in appearance and weighed 5.5 Gm. The blood pressure was unchanged for 12 hours when it decreased to 70/60. The temperature rose to 38.2° C. eight hours after operation, rising to 40° C. at 20 hours. The patient died in shock 36 hours after removal of the second adrenal. At no time were the values for serum sodium and potassium abnormal, and the blood sugar ranged from 82 to 131 mg. per cent.

Prior to castration the total neutral urinary 17-ketosteroids ranged from 5 to 7 mg. per 24 hours (Fig. 1). Following orchiectomy there was no immediate change in these values, but from day 13 to 20, the 17-ketosteroids fell to less than the preoperative level; however, over the course of a few months to a year and a half they gradually rose to

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\* All phosphatase results are expressed in King and Armstrong units per 100 cc. of serum.



12 mg. per day, almost twice the level found prior to castration. Following removal of the left adrenal gland there was a moderate decrease in 17-ketosteroid excretion; following right adrenalectomy there was a sharp reduction to a level of 2.0 mg. for the first 24 hours. Obviously, this patient did not live long enough for us to make any significant observations either clinically or chemically except that the treatment of acute adrenal insufficiency was inadequate.

Special therapy in this case included adrenal cortical extract\* 35 cc. intramuscularly on day 0 minus 1† 50 cc. on 0 day; and 50 cc. on 0 plus 1. Desoxycorticosterone acetate (DCA)‡ was injected in amounts of 5 mg. on 0 day and 20 mg. on 0 plus 1. A transfusion of plasma, 600 cc. was given on 0 plus 1.

Autopsy revealed adenocarcinomas of the prostate with metastases to lymph nodes and bone.

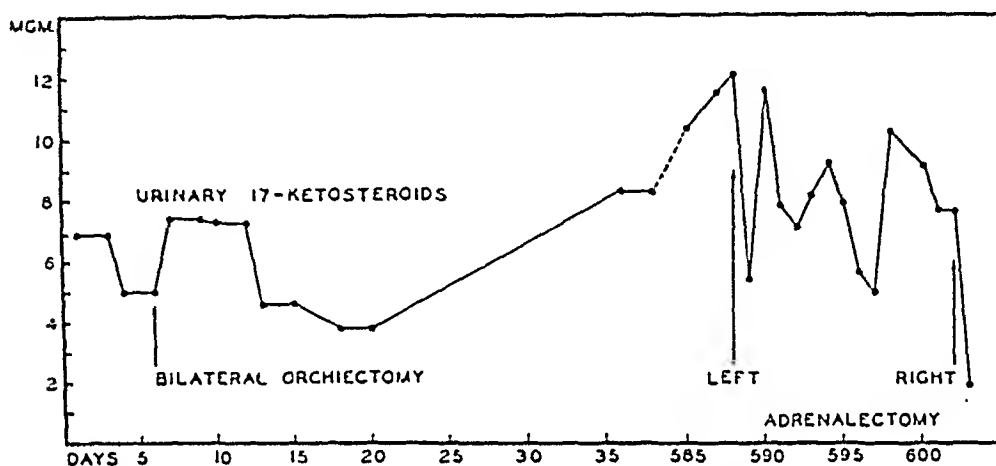


FIG. 1.—Excretion of total urinary 17-ketosteroids following orchiectomy and adrenalectomy, Case 1.

Case 2.—W. E. B. (history No. 312,344), a clerk, age 60, was first seen on June 23, 1943, complaining of pain in the lower back and in both legs for one month. For several years there had been urinary frequency. The prostate gland was large (4+), hard and nodular, and acid and alkaline phosphatase values were 3.75 and 24 units. A diagnosis of carcinoma of the prostate was made and bilateral orchiectomy performed on July 1, 1943, with complete relief of pain for five months, so that the patient resumed his work. The prostate became soft and atrophic except for slight induration in the left lobe. In December, 1943, sciatic pain recurred and became severe.

The patient was readmitted on May 7, 1944. The prostate gland was much smaller than before orchiectomy; the right lobe was atrophic and soft, the left lobe contained a hard nodule of walnut size. The blood pressure was 155/85. The left adrenal, weighing 5 Gm., was removed on May 12; the right adrenal, weighing 4.5 Gm., was excised on June 2, 1944.

Following complete adrenalectomy the temperature rose to 38.7° C. within eight hours and continued to rise (Fig. 2). Systolic blood pressure remained between 130 and 160 millimeters for 36 hours when it fell to 70 millimeters. The pulse was feeble and rapid, and the urinary output was low. The patient died in shock 54 hours after

\* Adrenal cortical extract used was the 10 per cent alcoholic extract of the adrenal glands, and was prepared by the Upjohn Company and the Wilson Laboratories.

† 0 minus 1 signifies the day before the operation; 0 is the day of operation, etc.

‡ We are indebted to Dr. Erwin Schwenk of Schering Corporation for the gift of this material.

adrenalectomy. Some degree of adrenal insufficiency followed the removal of the first adrenal gland as reflected by a lowering of serum sodium to 134 m. eq. per liter and an elevation of the serum potassium to 5.6 m. eq. per liter. These values for sodium were the lowest obtained for this patient and were determined on May 29, 1944. However, by the morning of June 2, 0 day, the values for sodium and potassium were normal, 141.2 and 4.3 m. eq. per liter, respectively.

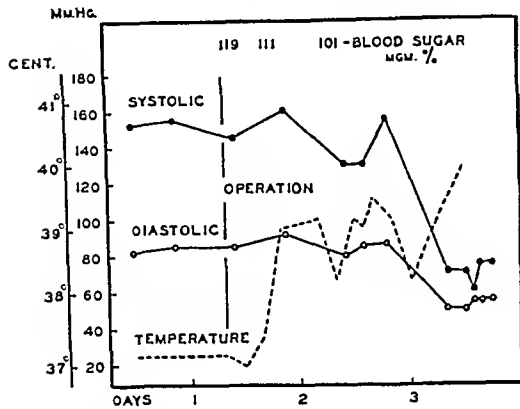


FIG. 2.—Decrease of blood pressure and increased body temperature in adrenal insufficiency of surgical type, Case 2.

Special therapy in this case included DCA, 10 mg. on days 0 minus 1, 0 day, 0 plus 1 and 0 plus 2; adrenal cortical extract 45 cc. on 0 day and 0 plus 2.

Autopsy revealed an undifferentiated carcinoma of the prostate, which appeared degenerated in many areas, with metastases to bones and lungs.

**Case 3.**—G. T. R. (history No. 269,817), a clerk, age 56, was first seen September 4, 1941, when he complained of urinary frequency for nine months and sciatica in the left leg for six weeks. The prostate was convex, hard and nodular, with extracapsular infiltration, but roentgenograms of the pelvis were interpreted as normal. Acid

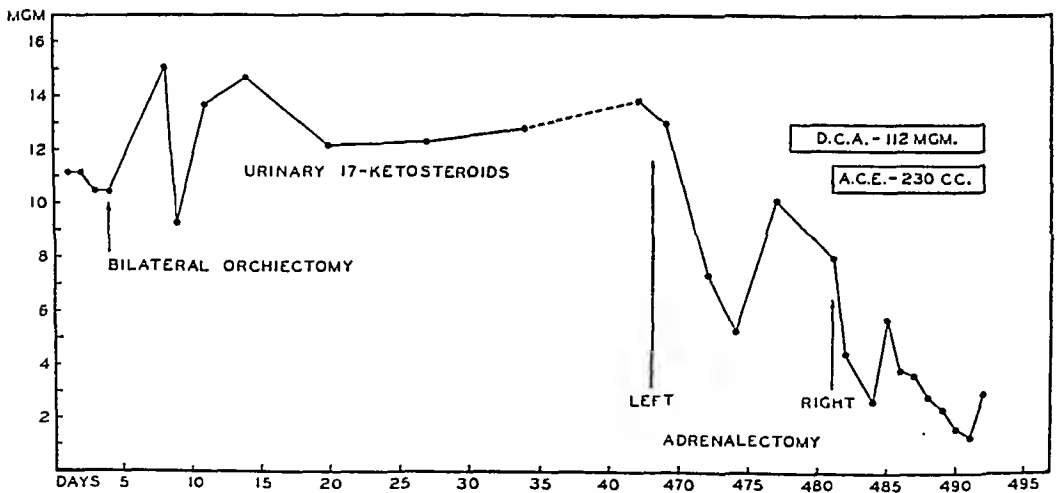


FIG. 3.—Decrease of total urinary 17-ketosteroids after adrenalectomy, Case 3.

and alkaline phosphatase values were 43 and 16 units respectively. Since the diagnosis of cancer of the prostate was certain, the testes were removed on September 16, 1941. The symptoms were improved and the patient returned to work. One year postoperatively the serum phosphatases were normal; the patient felt well and the prostate was soft, atrophic and without clinical evidence of carcinoma. One month later sciatica appeared in the right leg and rapidly became severe and required morphine and the patient was readmitted on December 22, 1942. At that time the prostate was atrophic, and the blood pressure was 134/72. Roentgenograms showed osteoplastic metastases in the pelvis. Acid and alkaline phosphatase values were 7 and 40 units. The left adrenal, weighing 5.5 Gm., was removed on December 30, 1942. The right adrenal weighed 6.5 gm. at removal on January 11, 1943. The temperature rose to 39.4° C. within four

hours thereafter and the blood pressure fell to 70/40 in 16 hours. The postoperative period was very stormy. During the early postoperative period the blood pressure and the urinary output were low; later the systolic blood pressure was increased to 150 millimeters and the daily output of urine was increased, but the patient became edematous, his fever persisted, and he died on o plus 11. The serum sodium and potassium were respectively 143 and 5.6 m. eq. per liter on o plus 8. Alkaline phosphatase values decreased from 40 to 11 units during the period of survival after complete adrenalectomy.

Preliminary total urinary 17-ketosteroids ranged from 10 to 12 mg. per 24 hours. Unlike the majority of patients we have studied these values did not undergo a preliminary decrease after orchiectomy, but rose instead, the rise being sustained for a period of 470 days (Fig. 3). After removal of the left adrenal there was a gradual fall in urinary ketosteroids; after removal of the right they continued to fall reaching their lowest value of 1.4 mg. per day on o plus 9 day. These values for 17-ketosteroids occurred in spite of the administration of desoxycorticosterone acetate and adrenal cortical extract. Comb-growth androgens determined before either adrenal was removed were of the order of 25 I. U. per day. Zero values were obtained on o plus 9 day indicating total absence of androgen excretion.

At autopsy, carcinoma of the prostate was found; there was marked regression of the primary tumor associated with very malignant metastases to bone.

Case 4.—F. A. (history No. 315,065), a blond laborer, age 45, was first seen on August 4, 1943, complaining of progressive urinary frequency and dysuria for one year. The prostate was firm, nodular and fixed. Acid and alkaline phosphatase values were 6 and 11 units, respectively, and roentgenograms showed a normal pelvis. On August 11, 1943, the testes were removed, and a biopsy of the gland through a perineal incision revealed an undifferentiated cancer of the prostate. For the next eight months the patient was relieved of his symptoms. The nodularity and induration of the prostate disappeared.

Ten months after orchiectomy the patient developed sciatica and began to lose weight, amounting to 10 kg. by the end of the 14th month. The sciatic pain became severe and morphine was prescribed. He developed edema of the thighs.

On November 11, 1944, the left adrenal gland, weighing 5 Gm., was removed, under spinal anesthesia, through a loin incision, and the right adrenal gland, weighing 5 Gm., was similarly excised on December 4, 1944. The immediate convalescence was uneventful; blood pressure was maintained at the preoperative level and there was a fever of 38° C. only on two days, o plus 4 and o plus 8. The details of pre- and postoperative treatment are given in Table I. The patient walked on the 8th day. The sciatic pain was relieved after operation but the appetite was poor. The serum sodium fell to 132 m. eq. per liter after removing the first adrenal, and at this time the serum potassium was 5.6 m. eq. per liter. There was no further reduction in serum sodium or potassium following complete adrenalectomy. Two months after the remaining adrenal was excised, the serum sodium was 140.5 and the serum potassium 5.0 m. eq. per liter.

On December 20, 1944 (o plus 16) brown-black pigment was noted under the eyes and beneath adhesive strapping in the loin areas; the prostatic bed was soft and smooth and presented no clinical evidence of carcinoma, and the patient was discharged from the hospital. Pigmentation increased in the fingers, external genitalia and near the incisions, especially around the site of the drains, skin sutures and where adhesive tape had been located.

There followed a period of poor health featured by lack of appetite, occasional vomiting and loss of weight. On February 7, 1945, urinary retention occurred which was treated by inlying catheter. Pubic and axillary hair became sparse. A decrease of pain, estimated at 75 per cent, occurred following adrenalectomy, but opiates were still required. During the last two weeks of life there was recurrence of slight edema of the legs. The patient died 116 days after complete adrenalectomy.

The urea clearance was 45.9 cc. (85 per cent of mean normal) three weeks before death, when the patient was receiving 25 mg. of DCA daily, and phenolsulfonephthalein excretion in two hours was 85 per cent of the amount injected; blood urea was 9.3 mg. per cent. The red blood count was 4.3 millions on January 14, 1945, 3.52 millions on February 22 and 2.72 millions on March 8, 1945.

Figure 4 illustrates the urinary 17-ketosteroids during the period before and after bilateral adrenalectomy. It should be recalled that bilateral orchiectomy had been performed 15 months before these studies. In spite of no hormonal medication between

TABLE I

## SUBSTITUTION THERAPY FOR TOTAL ADRENALECTOMY\*

	0 minus 1 day	
D C A	5 cc. intramuscularly	10 A.M.
Adrenal cortex extract	5 cc. intramuscularly	6 P.M.
Adrenal cortex extract	5 cc. intramuscularly	10 P.M.
	0 day	
Adrenal cortex extract	10 cc. intramuscularly	6 A.M.
Adrenalectomy		8 A.M.
D C A	5 mg. intramuscularly	9 A.M.
Adrenal cortex extract	20 cc. intravenously	9 A.M.
Plasma	500 cc. intravenously	9 A.M.
Dextrose 5% in water	500 cc. intravenously	9 A.M.
Adrenal cortex extract	10 cc. intramuscularly	Each hour until 8 P.M.
Plasma	500 cc. intramuscularly	7 P.M.
Dextrose, 5% in water	500 cc. intramuscularly	7 P.M.
Adrenal cortex extract	5 cc. intramuscularly	Each hour
	0 plus 1 day	
Adrenal cortex extract	5 cc. intramuscularly	Each hour until 8 A.M.
Plasma	500 cc. intramuscularly	8 A.M.
Dextrose, 5% in water	500 cc. intramuscularly	8 A.M.
D C A	5 mg. intramuscularly	8 A.M.
Adrenal cortex extract	5 cc. intramuscularly	Every second hour until 8 P.M.
Adrenal cortex extract	5 cc. intramuscularly	Every three hours until 8 A.M.
	0 plus 2 days and 0 plus 3 days	
D C A	5 mg. intramuscularly	8 A.M.
Adrenal cortex extract	5 cc. intramuscularly	Every four hours
	0 plus 4 days	
D C A	5 mg. intramuscularly	8 A.M.
Adrenal cortex extract	5 cc. intramuscularly	Every six hours
	0 plus 5 days	
D C A	5 mg. intramuscularly	8 A.M.
Adrenal cortex extract	5 cc. intramuscularly	Every eight hours
	0 plus 6 days	
D C A	5 mg. intramuscularly	8 A.M.
Adrenal cortex extract	5 cc. intramuscularly	Every twelve hours
	0 plus 7 days	
D C A	5 mg. intramuscularly	8 A.M.
Adrenal cortex extract	5 cc. intramuscularly	8 A.M.
	Succeeding days	
D C A	5 mg. intramuscularly	8 A.M.

\* We are indebted to Professor George W. Thorn of Harvard University for suggesting this regimen; without his aid prolonged survival would hardly have been possible.

removal of the left and right adrenal glands these values are higher than before the removal of the left adrenal gland. This phenomenon was not observed previously. Following removal of the remaining adrenal gland, the level of urinary 17-ketosteroids, total, ketonic and *alpha* fractions, rapidly fell and remained low for 116 days, the duration of survival. These total values are higher than the actual amount of 17-ketosteroid present in that crude color as the result of impurities adds to the total color of the reaction. This is apparent from the ketonic fraction and from studies made in which the entire

urine for the last 49-day period was extracted. During this period there was excreted on average 1.0 mg. per day of ketonic 17-ketosteroid. Further purification by means of chromatographic absorption technic reduced this to less than 0.7 mg. per day. At least one crystalline substance has been isolated from this 49-day collection but as yet has not been identified.

Of interest in Case 4 was the continued excretion of estrogen in the urine after both the testes and adrenals were removed. This patient excreted about five International Units of estrogen per day, expressed in terms of *alpha* estradiol benzoate, for a period of 41 days following adrenalectomy. The source of this estrogen is speculative but may have been degradation of desoxycorticosterone acetate or adrenal cortical extract.

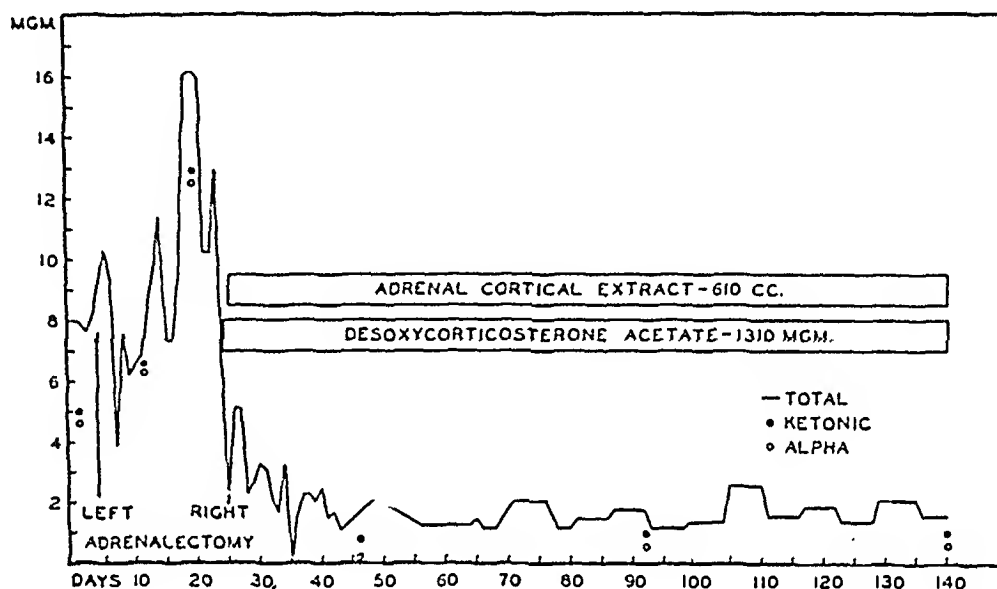


FIG. 4.—Decrease of alpha, ketonic and total urinary 17-ketosteroids following complete adrenalectomy with survival for 116 days, Case 4.

DISCUSSION.—In Cases 1 and 2 the substitution therapy was obviously inadequate since these men died 36 and 54 hours after complete adrenalectomy. The most striking effects of immediate surgical adrenal insufficiency are fever and hypotension, with death in shock; here fever of 38° to 40° C. arose within eight hours, and was maintained until death. The blood pressure remained at a normal level for 12 and 36 hours when it decreased to a shock level. The carbohydrate metabolism was not drastically affected since the level of blood glucose was not decreased and hypoglycemic convulsions were never seen. Lowering of serum sodium and elevation of serum potassium was not profound, and these levels were as much affected by removal of one adrenal as both. We are of the opinion that the large transfusions of plasma are of great aid in preserving life.

A significant effect following adrenalectomy was the rapid fall in urinary 17-ketosteroids, a fall which was persistent in the patient surviving 116 days. There has been previous, suggestive evidence that the testes and adrenals are the chief sources of the urinary 17-ketosteroids. Fraser, *et al.*,<sup>11</sup> giving total values of 14 and 9 mg. per 24 hours for the average excretion of 17-ketosteroids in the male and female, respectively, have postulated that 5 mg. comes from the testes and the remainder from the adrenal. Further evidence for this

concept is given by the markedly diminished or absent 17-ketosteroid excretion in the female with Addison's disease.<sup>11, 12</sup> Direct proof, however, such as was afforded by total absence of the testes and adrenals, has been lacking until the present study.

The rapidity of onset of pigmentation is of considerable interest. Sixteen days after complete adrenalectomy in Case 4 dark brown pigment was first observed in the lower eyelids, over the skin of the back and at the site of ad-

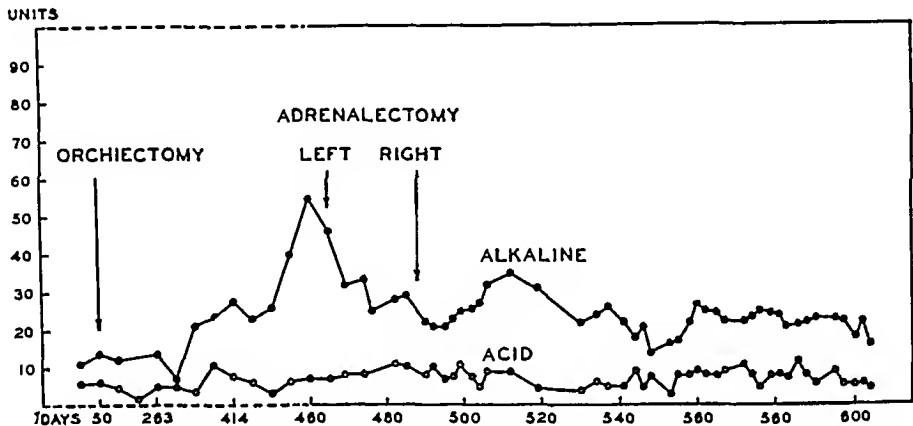


FIG. 5.—Rise in alkaline phosphatase 1 year after orchietomy with a decrease after adrenalectomy although not to normal levels, Case 4. The phosphatase values are expressed in King and Armstrong units per 100 cubic centimeters of serum.

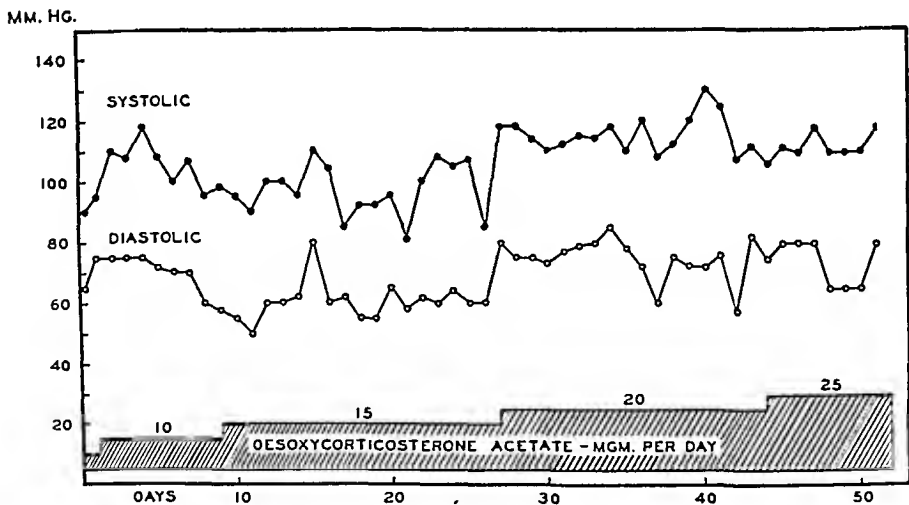


FIG. 6.—Failure to develop hypertension with increasing dosage of desoxycorticosterone acetate in an adrenalectomized man, Case 4.

hesive strapping. This coloration increased and appeared on the dorsum of the hands and on the external genitalia. The feet were uninvolved. The early appearance of this pigmentation was significant; pigmentation does not occur early in Addison's disease. The fact that the pubic and axillary hair became sparse was interesting.

The alkaline phosphatase of the serum decreased considerably after removal of both adrenals (Fig. 5) although not to normal values. This signifies a reduction in osteoplastic activity. The primary tumor also underwent a decrease in size and hardness as compared with the preadrenalectomy findings.

The effect of desoxycorticosterone acetate on blood pressure of the adrenalectomized man was of interest in that hypertension was not produced. Loeb,<sup>13</sup> Thorn,<sup>14</sup> and others,<sup>15</sup> have demonstrated the considerable rise in blood pressure occurring in Addison's disease as a result of overtreatment with DCA. In five of the six cases reported by McCullough and Ryan<sup>16</sup> hypertensive levels were reached with hormonal dosage of 10 mg. daily, or more. Clinton and Thorn<sup>17</sup> have found in normal subjects that a striking increase in plasma volume with retention of sodium and chloride followed the administration of 10 mg. of DCA daily.

Thorn, Koepf and Clinton<sup>18</sup> have described a syndrome characterized by excessive loss of salt and water resulting in collapse as a result of renal disease; these authors observed that adrenocortical hormones were of no effect apparently because damage to the renal tubules rendered them unresponsive to these agents while permitting excessive loss of sodium and chloride. In Case 4 in the present paper, DCA was effective in maintaining blood pressure at normal values but hypertension was not achieved with amounts of 25 mg. daily (Fig. 6) even with addition of sodium chloride, 8 Gm. daily, to the diet; the maximum blood pressure of 130/70 was obtained with a daily DCA dosage of 20 mg. Renal damage of severe grade was eliminated from consideration in this case since phenolsulfonephthalein excretion, blood urea and urea clearance values were within the normal range. This case is, therefore, exceptional with respect to resistance to DCA, but the reason for the lack of response is not clear.

Advancing carcinomatosis in man with low androgenic activity calls for a reëxamination of the factors involved in prostatic cancer. Three factors may be discerned at the present time, namely, the testicular androgens; the extragonadal androgenic depot (which may now be stated to be the adrenal glands exclusively); and androgen-independence. In many patients widespread carcinomatosis undergoes involution, both extensive and prolonged, following excision of the testes; here clearly the tumor is androgen-dependent and the testes are producing a highly significant fraction of male hormone. In a very few cases estrogen is required after orchiectomy to control the neoplastic activity and the extragonadal depot may be postulated as a complicating androgenic factor.

The androgen-independent cancers are those in which antiandrogenic therapy fails. Following castration of normal males the prostate undergoes great reduction in size and there is a cessation of secretion; the epithelium of the normal prostate shrinks markedly in size *but the epithelial cells do not disappear*. Androgen is responsible for the development of the prostatic cells and alveoli, but having developed they acquire a value which permits survival

(in a vestigial condition) in the androgen-free state and, thus, are androgen-independent. Androgen-independence is not remarkable since it is physiologic; what is noteworthy is the necessity for many of the prostatic cancers to be furnished with androgen for their continued activity.

### CONCLUSIONS

Abundant use of plasma transfusions seems to be of great importance in preventing circulatory collapse following adrenalectomy in man.

Inadequate therapy after adrenalectomy in man results in early hyperpyrexia and hypotension; the carbohydrate metabolism is not drastically disturbed. In the adrenalless man adequately treated with plasma, adrenal cortical extract and desoxycorticosterone acetate these effects were not observed but addisonian pigmentation occurred on the 16th postoperative day, and was progressive.

Complete adrenalectomy in castrate man results in a reduction of 17-ketosteroids to values less than two milligrams excreted in the urine daily; total, ketonic and *alpha* fractions are greatly diminished. Urinary androgens as measured by the comb-growth technic were absent. There is a continued excretion of small amounts of estrogen. In a man who survived complete adrenalectomy for 116 days there was a sustained reduction of alkaline phosphatase activity of the serum but the prostatic cancer progressed, although apparently at a retarded rate. DCA elevated blood pressure to normal levels but hypertension did not occur with massive doses.

The extragonadal androgenic depot in man is the adrenal.

Adrenalectomy is not a practical method of treatment of the failure-group of patients with prostatic cancer treated by antiandrogenic methods.

Three factors, whose presence and significance vary in the human prostatic cancers, may be stated: They are the testicular androgens; the extragonadal depot; and androgen-dependence or its opposite, -independence. It is not yet possible to define androgen-dependence or -independence in chemical terms.

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# SUBTOTAL REPLACEMENT OF THE SKIN OF THE FACE

FOR ACTINODERMATITIS DUE TO ROENTGENOTHERAPY:  
WITH MULTIPLE AREAS OF SQUAMOUS CELL CARCINOMA

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ALTHOUGH SKIN GRAFTS about the face are the subject of frequent reports, the replacement of all the skin of the face except for the eyelids and forehead is somewhat unusual.<sup>1</sup> A case is herewith presented in which skin grafts were used to replace the skin from ear to ear across the face from just below the eyes to beneath the chin and along the under side of the mandible. In addition, a nasal reconstruction was performed.

**Case Report.**—Mr. M. was 46 years of age when admitted to the University of Chicago Clinics and Hospital. He gave a history of having received a series of 25 roentgen ray treatments about 15 years previously. These were given for the most part over a period of four months for a pustular dermatitis of the face, which the patient described as "barber's itch." Other than evidence of a burn from the roentgen ray treatments the patient did not notice anything unusual about his face until the past two or three years during which time small weeping lesions would appear which would crust over. When the crusts were removed there would be a small ulcerated area. These would cause burning and itching. About seven months previously he noticed a lesion such as this developing on his nose. This became progressively worse.

At the time of his admission his general physical examination was essentially negative except for his face and neck. There were multiple small crusted lesions about the face and especially the nose. The intervening skin was white and scarred, and drawn tightly over his features. There were several enlarged, hard firm lymph nodes on the right side of the neck (Fig. 1).

The diagnosis was made of actinodermatitis from roentgen ray, with multiple areas of squamous cell carcinoma. It was presumed that the carcinoma was the result of malignant degeneration of the roentgen ray-damaged skin. In addition, there appeared to be metastatic carcinoma in the cervical lymph nodes.

The first procedure was a radical resection of the cervical lymph nodes on the right side of the neck. The microscopic sections confirmed the diagnosis of metastatic carcinoma of the lymph nodes. Subsequently, the lesion on the nose was excised. These first two procedures were done by Doctor Brunschwig. The patient was then transferred to my service for further work. The problem which presented itself was whether one should endeavor to locally excise multiple small lesions of squamous cell carcinoma which were present in several different parts of the face or, to do nothing further, pending the results of the radical resection of the lymph nodes of the neck, or to proceed with a wide excision of all the skin of the face which had been damaged by the roentgen ray.

The plan of procedure which was decided upon was the wide excision of all the roentgen ray-damaged skin along with the areas which had undergone malignant degeneration and replace this with extensive dermatome skin grafts for both sides of the face and lips and a pedicle graft for the nose. This was planned, of course, in multiple stages (Fig. 2).

The pedicle graft for the nose was prepared by making parallel incisions in the skin

## REPLACEMENT OF SKIN OF FACE

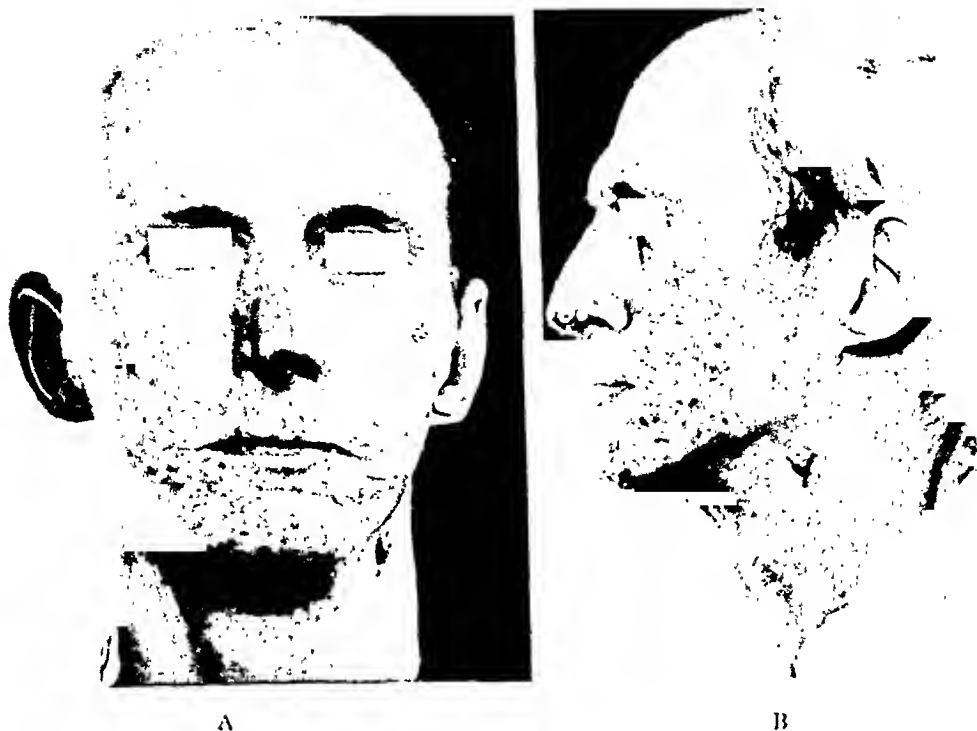


FIG. 1.—(A—Front view): Showing actinodermatitis of face from X-ray treatments given 15 years previously. There are multiple areas of squamous cell carcinoma which have developed in past few years which involve nasal tip, chin, cheek, and neck.  
FIG. 1.—(B—Side view).

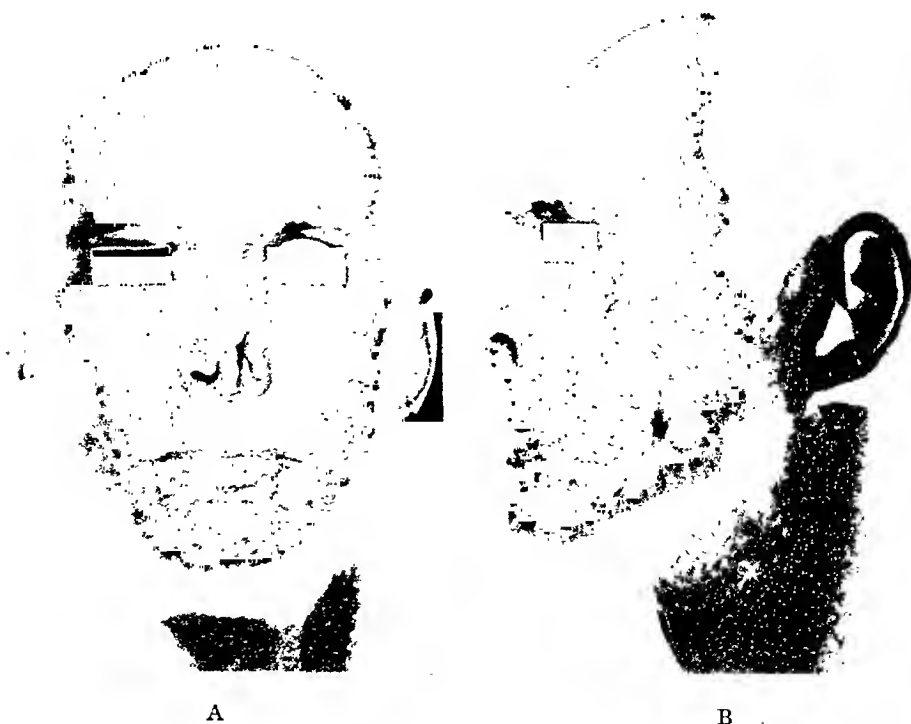


FIG. 2.—(A—Front view): Showing condition of nose following removal of squamous cell carcinoma of nasal tip.  
FIG. 2.—(B—Side view).

of the left arm and elevating the intervening skin and subcutaneous tissue from the muscular fascia. These incisions were then sutured with fine dermal sutures and allowed to heal over. After two weeks the upper ends of the outlined pedicle was cut across, the upper portion of the pedicle elevated and the skin then sutured with fine dermal. After another three weeks the entire pedicle was elevated by cutting again through the previously healed incisions. The defect was closed by pulling the skin together over this area. There was no evidence of impairment of the blood supply, and so the remaining skin of the nose was excised and the pedicle sutured into place. The arm was held in position by a plaster of paris encasement (Fig. 3). The base of the pedicle was cut across after two weeks, and the free end of the detached pedicle on the nose was then trimmed and moulded into shape to produce the nasal tip, columella, and alae.



FIG. 3.—Showing pedicle skin graft from arm to reconstruct the nasal tip and replace the rest of the skin of the nose.

After the graft to the nose was well healed, one of the more noticeable lesions which was on the left cheek was excised and the defect closed with a relatively small free graft. This was done because this lesion, which was another area of squamous cell carcinoma, was ulcerated and infected and it did not seem advisable to include such an area in the region of a large graft. The next stage was the wide excision of the skin of the left side of the face. This was begun in front of the ear and extended across the face, under the eyes to the skin of the reconstructed nose. The skin was left on the upper and lower lip and the angle of the mouth up to a line where a crease in the skin would normally occur when smiling. The excision of skin was extended down to the under side of the mandible. The removal of the skin was carried out by sharp dissection from the underlying tissues. Constant irrigation with isotonic saline was carried out during the dissection. Bleeding points were clamped with small hemostats which were subsequently released after all the skin was removed. Persistent bleeding

points were then ligated with No. 5-0 silk. A cardboard pattern was cut to fit the defect. A dermatome skin graft was removed from the abdomen, 15/1,000 inch in thickness, and trimmed to match the cardboard pattern. The graft was sutured into place along the margins of the defect with No. 5-0 solid filament silkworm gut which was provided with a fine curved needle swedged on the suture. No fenestrations were made in the graft.

In addition, a small lesion on the side of the neck was locally excised. An emulsion ointment of sulfathiazol<sup>2</sup> was applied over the graft and a mechanic's waste pressure dressing applied. The dressings were not removed until two weeks after the operation, at which time the graft was found to be in relatively good condition.



FIG. 4.—(A—Front view): Showing result of extensive skin grafts to face nine months after completion. The nose was reconstructed from a pedicle from the arm. The skin of the face was replaced from ear to ear and from below the eyes to beneath the mandible by dermatome skin grafts.

FIG. 4.—(B—Right side of face).

Two small ulcerated lesions, one on the chin and another on the right cheek were excised locally before proceeding with further grafting. Both of these were squamous cell carcinoma. The wounds resulting from the two small excisions healed over very slowly, and further grafting was postponed until complete healing had occurred.

The next major stage consisted of the removal of the skin of the right side of the face. This was performed in the same manner, and to the same extent, as was done on the left side of the face. The dermatome graft was taken from the back, and was 15/1,000-inch in thickness. Dressings were removed after two weeks and the graft found to be in good condition.

The final stage consisted of the removal of the remaining skin of the upper lip, lower lip, chin and angles of the mouth. The skin was removed up to the mucocutaneous line of the lips. A dermatome graft was trimmed to a cardboard pattern of the defect and then cut transversely in the center to provide for the mouth. This part of the graft was sutured to the mucous membrane of the lips and angles of the mouth at the vermilion border. The periphery of the graft was sutured to the margins of the defect which on either side consisted of the edges of the previous grafts. Sulfathiazol ointment dressing was applied and an attempt to maintain pressure on the graft with a mechanic's waste dressing was not especially satisfactory. It was necessary to remove the dressings after six days. Several serum accumulations were evacuated with a fine needle and syringe. Most of the graft remained viable but there were several small areas of necrosis. These areas ultimately healed over without requiring further grafting.

The various stages of this subtotal replacement of the skin of the face was done under local anesthesia using 0.5 per cent novocaine.

There was some degree of scarring which remained at the junction of the graft about the mouth with the large lateral grafts, which was not entirely satisfactory from a cosmetic standpoint at the time the patient was discharged from the hospital.

The length of the hospitalization for the reconstruction procedures was nine months. Seven months after discharge, the patient returned for a check-up. At this time the grafts were soft and pliable and the junction of the major grafts was not easy to detect (Fig. 4). There was no evidence of recurrence of the squamous cell carcinoma.



C

FIG. 4.—(C—Left side of face).

The patient returned again a year later (two years after the radical resection of the metastatic carcinoma in the cervical lymph nodes). At this time, the skin grafts of his face were in excellent condition. It was very difficult to identify the junction of the major grafts. The skin was soft and pliable and moved freely with the face muscles. There was no evidence of recurrence of the carcinoma in the field which had been grafted. The reconstructed nose was in good condition. The patient had been advised to avoid direct sunlight on his face to avoid pigmentation of the grafts. At this time, the color of the grafts was, of course, lighter than the skin of his forehead. The patient had not found it necessary to use a cosmetic on the grafted area and had not been disturbed by such differential in color as was present. From the standpoint of obtaining a better color-matching in such cases, one should, of course, consider the possibility of resorting to the tattoo method, described by Hance, Brown, Byars, and McDowell.<sup>3</sup> Simple cosmetics, and especially "Covermark," can generally suffice in most instances.

From the standpoint of reconstruction surgery, this patient represented a very satisfactory end-result from extensive skin replacement. However, a hard nodule was found on the right side of his neck at about the level of the angle of the mandible. This was explored and found to be recurrent squamous cell carcinoma. The tumor mass was

adherent to the internal carotid artery for a distance of 3 cm. beyond the junction with the common carotid. The mass was dissected from the wall of the internal carotid without damaging the vessel. It was not deemed advisable to risk an hemiplegia by resecting the internal carotid which had been adherent to the tumor mass. A radium plaque was subsequently applied to this area in an attempt to control the growth of any tumor tissue which may have been left on the vessel wall. The patient made a satisfactory recovery from these procedures. However, the ultimate outcome is awaited with some degree of apprehension.

COMMENT: This case report is presented to illustrate what can be done in the way of extensive replacement of the skin of the face. There are numerous instances of patients who have received roentgen-ray burns of the skin of the face. Some of the more severe burns may undergo malignant degeneration of the damaged skin. If one awaits the malignant change, and the subsequent metastases to the cervical lymph nodes, the opportunity for a permanent cure is not good. The very satisfactory cosmetic result which was obtained in this case poses the question as to whether one would not be justified in undertaking such extensive removal and replacement of the skin of the face for severe roentgen-ray burns before there is definite evidence of carcinomatous change. This would constitute a prophylactic measure in the treatment of a precancerous lesion which may at some time become carcinomatous and subsequently invade the regional lymph nodes, as occurred in this case. In addition, the cosmetic result would be more acceptable than the severe roentgen-ray burn of the face. In such cases it would probably be desirable to use a free graft to replace the skin of the nose instead of a pedicle graft which was necessitated in this patient because of the removal of the nasal tip. Furthermore, there may be a wider field for the use of such large grafts to replace the skin of the face which has been severely scarred from acne alone, without the superimposed damage from roentgen ray. The smooth, soft texture of the skin graft would offer an improvement over the irregular scarred surface of the skin in very severe cases of acne. Severe thermal burns involving the entire face would probably constitute the widest field of usefulness for extensive grafts such as were employed in this case.

#### SUMMARY AND CONCLUSIONS

A case of severe actinodermatitis of the face from roentgen ray, associated with multiple areas of squamous cell carcinoma is presented. This was treated by extensive removal in stages of all the skin of the face except for the eyelids and forehead, and replacement by dermatome skin grafts in three major stages, and a delayed pedicle graft from the arm to the nose in four stages. The satisfactory cosmetic result which was obtained in this case, raises the question as to whether this type of procedure, with some modifications, may not be appropriate for severe roentgen ray burns of the entire face as a prophylactic measure before carcinomatous changes occur, as well as on the basis of the cosmetic improvement which may be obtained.

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# CONGENITAL CATARACTS FOLLOWING RUBELLA IN PREGNANCY

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THE IMPORTANCE of an exanthematous disease in the production of congenital cataract was first emphasized by Gregg<sup>1</sup> before the annual meeting of the Ophthalmological Society of Australia, in 1941. An unusual number of cases of congenital cataract scattered throughout Australia in 1941 appeared as a mild epidemic.

In 14 months, with the aid of his colleagues, Gregg collected a series of 78 cases of congenital cataracts occurring in infants. The cataracts were evident at birth, and were generally bilateral. The dense lenticular opacity was nuclear and was surrounded by a zonular haze and later by an outer clear zone. In some cases the lens was totally opaque centrally. The vision was apparently good except for the lenticular opacity. After three months searching movements occurred in the cases with bilateral cataracts because of the lack of development of fixation.

Out of 78 cases, 16 cases showed unilateral cataracts. In ten of these the eye was microphthalmic. The pupils were difficult to dilate because the infants tolerated atropine poorly. A general examination showed a congenital cardiac defect in 44 cases. At autopsy, a widely patent ductus arteriosus was discovered in three infants. In this series of cases, 15 patients died from bronchopneumonia, or unknown causes. All of the cases showed mental retardation, and most of them were feeding problems.

The frequency and geographic incidence suggested the cause was an infectious disease during pregnancy. The type of lesion led to the assumption that the disease damaged the lens during the formative period of the first few months of pregnancy. The calculation of the early months of pregnancy from the time of the birth of the child corresponded to the widespread and severe epidemic of rubella in Australia in 1940. An inquiry into the state of the health of the mother usually led either to the symptoms or to the diagnosis of German measles as the exanthematous disease during the second or third month of pregnancy. Because of the remarkable congenital defects, Gregg doubted whether the disease was true rubella.

Consequently, the National Health and Medical Research Council immediately sponsored a team of specialists to collect and correlate data of other similar cases in South Australia. Permission was requested of all medical practitioners to interview the mother and to examine the infant in all cases in which the mother had an acute exanthematous disease during pregnancy, even if the child was normal.

A series of 74 cases, covering the years 1939 to 1943, was investigated and was presented in two excellent reports<sup>2, 3</sup>. A definite history or diagnosis

of rubella in pregnancy was obtained in 61 mothers. Twenty infants had no evidence of the effect of rubella. The mothers of these infants had rubella

TABLE I

LIST OF ABNORMALITIES IN THE TWO SERIES OF CASES OF SWAN,  
ET AL., DIAGNOSED AS RUBELLA IN PREGNANCY

Unilateral cataract.....	1
Unilateral cataract, heart lesion.....	3
Bilateral cataract.....	5
Bilateral cataract, heart lesion.....	4
Bilateral cataract, heart lesion, mental deficiency.....	2
Bilateral buphthalmia, heart lesion, mental deficiency.....	1
Microcephaly.....	2
Microcephaly, mental deficiency.....	1
Heart lesion.....	8
Heart lesion, deaf-mutism.....	3
Deaf-mutism.....	9
Obliteration of bile ducts.....	1
Hypospadias.....	1
No abnormalities related to rubella.....	20

late in pregnancy. Of the 41 infants who had congenital abnormalities (see Table I), the mothers generally dated their rubella before the fourth month of pregnancy. The infant frequently had more than one organ affected. Out of the 15 patients having cataracts, 11 were bilateral and four unilateral. One patient had bilateral buphthalmia. The disease early in pregnancy from the first three weeks to the end of the third month tended to damage the eyes. Cataract was the common ocular disease. Microcephaly occurred in three infants but it was not obvious until later in the growth of some children. Mental retardation was evident in four infants. The loss of vision or hearing and the age of the child prevented the establishing of diagnosis of mental deficiency. With the handicap of loss of these senses it was difficult to estimate the mentality of the infants. Congenital deaf-mutism was present in 11 infants. The deafness was not complete but was in the low tones. Heart lesions were discovered in 21 infants. In some cases the positive clinical evidence of heart disease was not confirmable upon roentgenologic examination. The roentgenologic examination often revealed heart abnormalities not discovered clinically. The common heart lesions found at autopsy were patent ductus arteriosus, intraventricular septal defects, and patent foramen ovale. The heart was affected early in the pregnancy in the first three months. Later, Swan<sup>5</sup> mentioned hyalinization and sclerosis in the glomeruli of the kidney in a few patients, and Evans<sup>6</sup> noticed dental aplasia was a common defect. Young<sup>4</sup> later reported a case of deafness in an infant who had rubella at the age of four months.

Swan, *et al.*, believed that the reason for the lack of previous observations on the association of cataracts with rubella in pregnancy was related to the increase in the severity of the disease during the past few years in Australia, Great Britain and the United States. Other reports<sup>7, 8, 9</sup> have suggested an increase of virulence or a shift in the activity to other tissues as a cause for the severity of the disease. Some of the congenital cataracts

and other abnormalities in cases which were listed by Swan but included in the series of cases with undoubted rubella were perhaps related to mothers with mild or no symptoms of rubella.

Reese<sup>10</sup> reported on three cases of cataract following a severe epidemic of German measles. One infant with a congenital heart lesion had an unilateral cataract in a microphthalmic eye. In the second infant which was microcephalic there were cataracts in each microphthalmic eye. The heart lesion was diagnosed as patent intraventricular septum. The third infant had bilateral cataracts in microphthalmic eyes. The heart had a patent ductus arteriosus. No operations were performed to remove the cataracts.

Erickson<sup>11</sup> listed the brief data on 11 cases. Bilateral cataracts were evident in seven infants, unilateral cataracts with microphthalmia in two, unilateral microphthalmia in one, and unilateral corneal opacity with microphthalmia in one infant. Nine infants had congenital cardiac defects and two had mental retardation.

Perera<sup>12</sup> has recorded one case. The infant, age 4.5 months, had an unilateral congenital cataract and cardiac disease. After operation the lens was still absorbing slowly.

The total number of cases in which pregnant women were diagnosed as having rubella were 68 by Gregg (10 of 78 were discarded by Swan, *et al.*, as insufficient histories of rubella infection), 41, by Swan, *et al.*; 3, by Reese; 11, by Erickson; and 1, by Perera, or a total of 124 cases. Of the 124 cases, 96 had cataracts.

A series of rubella cases which were seen at the University of Chicago Clinics is presented here.

#### CASE REPORTS

**Case 1.**—P. B. was born in an outside hospital on October 26, 1943, during a normal delivery after eight and one-half months gestation, with a weight of 1,100 Gm. She was kept in the hospital for two and one-half months until she weighed 2,720 Gm. At the age of three weeks the infant was found to have cataracts in each eye.

The father, age 25, and brother, age two, were always healthy. The mother, age 22, in the seventh week of pregnancy had the symptoms of rubella.

In February, 1944, the child was seen in the University Clinics. A diagnosis of prematurity, congenital heart disease, congenital displacement of the fourth toes and bilateral congenital anterior uveitis and cataracts were made.

On April 18, 1944, an eye examination was made. The child avoided light. No vision of moving objects was obtained. Externally the eyes were normal. The bulbs were small. The right cornea was 6.5 mm. and the left was 7.0 mm. in diameter. No precipitates were seen on the posterior surface of the clear corneas. The anterior chambers were very shallow. The irides were muddy-gray in color and had lost most of the pigment of the posterior epithelium. The pupils were 2 mm. in diameter and fixed by posterior synechiae. The pupillary reflex was pinkish-gray centrally and red peripherally. The lenticular nuclei were diffuse opaque gray and the cortex was almost clear. The anterior surface of the capsule was lightly covered with a fine gray veil and sprinkled with melanotic pigment granules. The lenses were slightly displaced up and in. The electrocardiograph indicated no definite abnormality. The roentgenologic examination showed an indistinct congenital vascular anomaly of the heart. The dental

development was delayed. Hearing appeared to be not subnormal. In spite of the loss of vision the child was not considered to be remarkably mentally retarded by the child psychologist.

On October 24, 1944, the eyes were reexamined. The corneas were then 8 mm. in diameter. The lenticular nuclei were denser. On October 30, 1944, a Barkan operation was performed on the right eye and a week later on the left eye. After the operations the fundi appeared normal except for the absence of the foveolar reflex. The child was given eight diopter glasses. A psychologic test showed that the child was greatly improved mentally.

This case is unusual because bilateral fetal iritis was present. The operation was successful in removing the opacity and in increasing the vision. The question of whether or not the iritis will remain quiescent and not cause obscuration of the vision cannot be answered as yet.

Case 2.—H. B., a white male, was born, April 17, 1943, in the University of Chicago Clinics after a gestation of 28 weeks. The child was not cyanosed or jaundiced. The healthy infant weighed 985 Gm. on the seventh day. The delivery was uncomplicated. The placenta was normal. No instruments were used. No cause was known for the prematurity.

The mother, a primipara, age 29, and the father, age 33, were healthy. The mother had rubella in the second month of pregnancy. Ocular, nervous and familial disease were not evident in the relatives of the parents.

The child was placed in an heated oxygen chamber. Vitamin K was given. On May 4, an upper respiratory infection caused a mild cyanosis and slight jaundice. After treatment with sulfathiazole the disease was cured. The hemoglobin dropped from 18.5 Gm. (Hayden-Hansen method) on May 2 to 8 Gm. on May 21. Intravenous blood transfusions brought the hemoglobin up to 11.5 Gm. on June 12. On October 20, the child was discharged from the hospital. The eyes appeared to be normal. The weight was 4,255 Gm.

In November, 1943, the mother noticed that the child did not see objects or light and did not pick up anything unless it was placed in his hand. Several physicians examined the child and suggested that cataracts caused the blindness.

On July 27, 1944, an examination was made. The child was normal physically. The Wassermann test of the mother was negative. The blood count, hemoglobin and urine of the child were normal. Roentgenologic examination of the skull and chest was negative. The fronto-occipital diameter of the head was 43.5 cm. The child showed, by psychometric tests, a marked mental retardation which was not related to blindness.

The eyes gave no reaction to light and turned in 15°. The external ocular movements were unrestricted. The bulbs appeared to be normal in size. The corneas were 11 mm. in diameter and were hazy posteriorly. The right anterior chamber was shallowed in the middle and absent peripherally where the iris was adherent to the cornea. The left anterior chamber was absent except inferiorly and nasally where it was extremely shallow. On the left iris, a prominent radial vessel extended to the pupil from below. Transillumination of the bulbs gave a pinkish-gray pupillary reflex. The intra-ocular tactile tension was low. The fixed pupils were irregular and adherent to the white opaque lens. The right pupil was 3 mm. in diameter and the left 2 mm.

The patient was last seen on July 29, 1944.

A diagnosis of bilateral fetal uveitis, bilateral congenital cataract, cerebral agenesis and mental retardation was made.

Case 3.—B. M. was born February 10, 1945, with a weight of 2,295 Gm. after a 28-week gestation. The mother had German measles during the second month of pregnancy. At birth, the corneas were slightly cloudy. After examination, a diagnosis of prematurity, with multiple congenital anomalies was made. The new born infant

had spina bifida with loss of function below T 12, congenital cardiac anomalies, congenital cataract of left eye. The infant died on the 30th day of life.

Uncontrollable circumstances did not permit a further examination of this and other infants.

Case 4.—J. P., born December 15, 1944, was a full term child who was seen at the age of 10 months. Two weeks before the first missing menstrual period of pregnancy the mother had German measles. The child was always mentally and physically retarded. A congenital cataract was removed from the left eye at the age of five months. The vision appeared to be fair.

An examination showed a left convergent strabismus, left postoperative aphakia, dental aplasia, bilateral total deafness, and mental and physical retardation. No cardiac abnormalities were found. The fundi seemed to be normal except for the absence of foveolar reflexes.

The interesting point in this history is the accurate-dated record of rubella two weeks after the last menstrual period.

Case 5.—R. S., born in 1942, was seen at the age of two years. The mother had German measles in the second month of pregnancy. The examination of the child revealed a loud apical and basal murmur in the chest, vision of gross objects particularly with the use of his left eye, in spite of bilateral lens opacities, fair hearing and a low mentality based on psychometric tests. A diagnosis of bilateral congenital cataracts, congenital heart disease, cerebral agenesis and mental retardation was made.

DISCUSSION.—Married women who know that rubella may give rise to congenital defects in children have asked about the possibility of becoming infected with rubella during early pregnancy. If the women are in contact with the migratory people from camps and cities they have a much better chance of infection than women who are relatively isolated. Husbands on leave from the Armed Forces may spread the disease to their wives. If the women had rubella in the past, the chances of having another attack of the disease are very remote. One mother in the Australian series of cases asserted that she had a previous attack of rubella. There are other rare instances in which a second attack has occurred.

Nonmedical persons have regarded rubella as a mild disease which needs little or no treatment. According to two Australian reports, about half of the 41 mothers with affected infants received medical counsel when they had the disease. The question arises whether or not the public, particularly married women, should be informed of the dangers of infection with rubella. If they are exposed to rubella in early pregnancy, treatment with convalescent serum should be considered. Perhaps it might be well to require that the disease, especially in married women of child-bearing age, be reportable to local or state public health service. Since these infants with serious congenital defects may have mental retardation, loss of sight and hearing and generally poor health, they are incapable of taking care of themselves. They represent a social problem.

Treatment should be considered in women with a questionable pregnancy or a pregnancy of the first three months with a history of rubella. The ratio of infants with congenital defects to those with no defects in mothers with rubella is too high to be disregarded. The only possible but presumptive

method of treatment seems to be the use of convalescent German measles serum.

Whether or not rubella can affect the fetus if the woman has the disease just before pregnancy is questionable. Gregg<sup>1</sup> reported one woman who had rubella three months before pregnancy but the infant had congenital rubella cataracts. There is no doubt that viruses may persist in the tissues but the persistence of the German measles virus is unknown. There seems to be little reason at present to give treatment before pregnancy or after six known months of pregnancy.

Perhaps induction of the disease before pregnancy may be a means of preventing the possibility of occurrence of the disease during pregnancy in those who are exposed to it.

A therapeutic abortion may be considered if the disease has occurred in the first four months of pregnancy.

The surgical treatment of these cases with congenital defects varies with the organ involved in the disease. The cataract should be treated surgically as soon as possible in the first few months of life, before the development of fixation. Time of operation makes a great difference in bilateral cataract. The type of operation will vary with the surgeon and his experience. The hard central lenticular nucleus should be removed. It usually takes a long time, sometimes months, before a clear pupil is formed after an operation. The absorption of lens substance, according to the experience of those who have operated on the rubella cataracts, is delayed. An operation at three months of age is late because by the time the pupil is clear the ability to develop fixation may be lost. The ophthalmologist usually sees these infants after the pediatrician or physician has treated the child for malnutrition. A common belief is held that these infants are too young for operative procedures on the eye. A better procedure would be to have the obstetrician consult the ophthalmologist as soon as the infant is found to have white pupils, poor sight, or as soon as the pregnant woman with a history of an exanthematous disease in the first four months of pregnancy is first seen by him.

All children with congenital cataracts related to rubella should have their hearing tested for range. Low tone deafness may be missed in ordinary tests. According to the report of Swan, *et al.*, hearing aids have been tried satisfactorily on a few infants. Deafness and deaf-mutism are added factors contributing to mental retardation.

The patent ductus arteriosus is a common defect in these infants, and is usually contributory to their poor health. A successful surgical procedure to correct this condition has been developed. In one case<sup>3</sup> this operation resulted in a distinct improvement of physical condition of the child.

#### SUMMARY

The literature on effect of rubella in pregnancy is reviewed. A report on five cases with congenital anomalies including cataract is given. Preventative, conservative and radical treatment of fetal rubella is discussed.

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# HEADACHE FROM LESIONS OF SCALP NERVES

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THE CAUSE of chronic localized headache is frequently a difficult diagnostic problem. In many instances there is apparently no intracranial disorder and the origin of the pain is entirely extracranial. Disturbances within the orbit and accessory nasal sinuses are commonly associated with the symptom of headache. The following observations are recorded to illustrate the fact that some cases of localized headache arise from lesions of nerves of the scalp. The discomfort may not be of a type that is commonly associated with peripheral nerve lesions. The sharp, shooting, lancinating and radiating character of the pain, usually termed neuralgic, may not be present and the complaint is simply that of headache.

## SCARS

Direct involvement of nerves to the scalp by scar tissue may cause headache without ready recognition of the relation of the scarring to the symptoms. In some instances a healed deep laceration in the region of the pain may be obvious. In others, the laceration may have been forgotten and not readily detected when examined through the covering of scalp hair. In still others, the history of closed contusion or previous infection producing scarring may not be elicited. Examples of these are cited:

## ILLUSTRATIVE CASE REPORTS

**Case 1.**—*Case of known laceration:* W. W., a Negro male, age 25, fell from the upper deck of a ship and incurred a deep lacerated wound of the right frontal region and a linear fracture of the left occiput. One month later, he attempted to return to work but remained disabled by reason of right-sided headache and some dizziness. Examination two and one-half months after injury revealed a markedly tender spot at the superior pole of the scar. Pressure on this spot, in addition to causing pain locally and radiating over the distribution of the supra-orbital nerve, reproduced his so-called headache. The symptoms continued and the patient discovered that wearing a hat or especially a shipworker's helmet aggravated the headache. Seven months after injury the painful area of the scar was excised. Histologic study showed nerve trunks of moderate size entering hyperplastic keloidal scar tissue with distortion and compression of these nerve trunks by fibrosis. The symptoms were relieved and have not recurred nine months postoperatively.

**Case 2.**—*Case with unrecognized scars:* T. O., a white male, age 26, with a moderate degree of cerebral spastic paralysis, complained of headache all his life, but of increasing severity the past year. The headache was most severe in the left occipital region. Dural denervation in the region of the left middle meningeal vessels gave little relief. At the time of this operation several small scars from old lacerations were noted on the shaved scalp in the left parieto-occipital region. These were definitely tender and later infiltrations with procaine relieved the headache for short periods up



to a week. The scars were excised together with division of the greater occipital nerve at the lambdoidal ridge. Sections of the scars showed small nerve bundles distorted by both intraneural and perineural fibrosis. While the localization of the headaches to the area operated upon has been abolished, intermittent occipital headaches are still present six months after excision of the scars, in addition to numerous other vague complaints.

**Case 3.**—*Case of headache after contusion:* E. E. R., age 23, was struck above the left eyebrow by a blunt object and was unconscious for three minutes. Intermittent left frontal headache followed and disabled him from work. On examination three months after injury, the left supra-orbital nerve was found to be markedly tender. Pressure over the nerve reproduced his headache. The nerve was injected at its exit from the skull with 95 per cent alcohol. In spite of a satisfactory analgesia to pin-prick, the headache, while ameliorated, has persisted to some extent and there is still some apparent tenderness over the nerve, three weeks after injection. Evaluation of the findings is difficult in the face of an obvious compensation neurosis.

**Case 4.**—*Case of headache associated with old infection:* C. F. R., age 28, white, male, complained of migraine for about 15 years. The attacks had gradually increased in severity and frequency, occurring in recent months as often as every five days. There had been also numerous episodes of furunculosis of the neck since adolescence. There was diffuse deep scarring in the posterior occipital region and definite tenderness over the region of the greater occipital nerve on the left, the side of the migraine. Branches of the nerve together with a block of scarred subcutaneous tissue were excised at the point of maximum tenderness. There were no headaches for nine months following this procedure, after which some recurrence of unilateral headaches every two to three months ensued. These are not as severe as preoperatively and are not increasing in frequency, three years after the excision.

#### TUMOR

The following case is one in which a tumor apparently was the cause of unilateral headache:

**Case 5.**—Mrs. C. F. C., age 33, complained of migraine for many years. Her attacks of headache occurred as often as once or twice a month, were always on the right, and radiated anteriorly from the occipital region. Nausea occurred occasionally. For two years she had noticed a flat swelling over the lower occiput on the right. This was soft, movable and tender only on firm pressure. At operation, a flat fibrolipoma,  $4 \times 3 \times 1.5$  cm., was found enveloping the greater occipital nerve below the lambdoidal ridge. It was excised. Sections showed a fibrolipoma with nerve bundles compressed in the dense fibrous trabeculations. The migraine headaches ceased for five months but then recurred and have continued to the present time, 26 months postoperatively. They are much less frequent than before but of considerable severity. The area of operation is again tender. It is likely that nerve regeneration into the scar has occurred.

#### "NEURALGIAS"

Many patients complaining of localized headache show tenderness over a nerve to the scalp without demonstrable pathologic explanation. Results of local treatment in such cases is notoriously variable. Occasionally, one or more subcutaneous injections of procaine or other anesthetic agent produce a prolonged amelioration. Ammonium sulfate injections, as advocated by Bates and Judovich, have been of benefit in some cases particularly in the region of the greater occipital nerve. Alcohol block has been useful for the

supra-orbital nerve, since the injection may be placed with reasonable accuracy in or about the nerve at its exit from the skull. Section with excision of a segment of the nerve is indicated for intractable cases. Routine pathologic studies in a number of these have shown no lesions in the nerve. Not infrequently the headache soon appears in a new location or after some months recurs in the same area, presumably as a result of nerve regeneration. Plugging the foramen with a wisp of cotton and bone wax at the time of nerve excision seems to limit regeneration of the supra-orbital nerve.

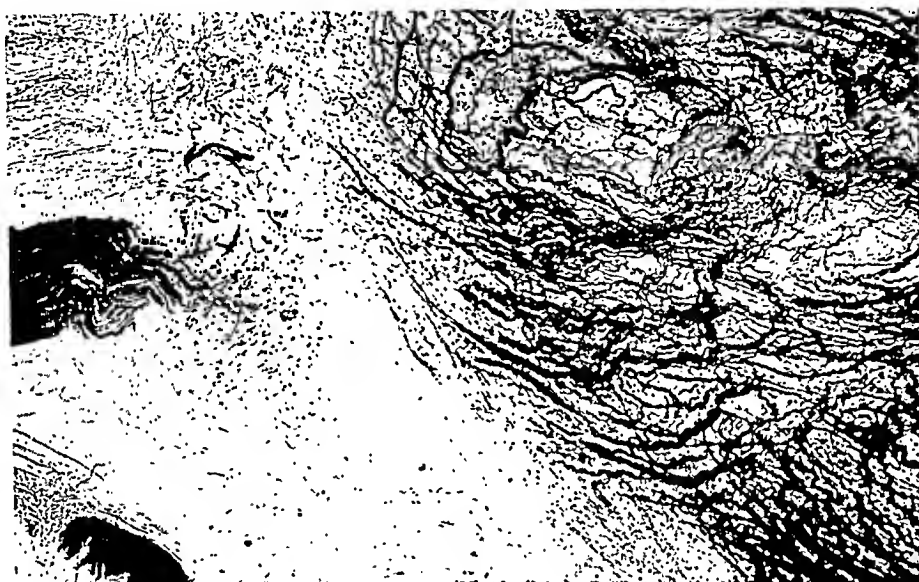


FIG. 1.—Cutaneous regeneration neuroma from a pedicled skin flap in a rabbit. Gros method  $\times 60$ . From studies carried out during the author's residency under Dr. Phemister.

#### NERVE REGENERATION

It has been recognized that even very small nerves after division manifest a tendency to regenerate. Thus recovery of sensation occurs in both free skin grafts and pedicled flaps.<sup>1</sup> Kredel and Phemister observed some recovery also of sympathetic function in skin transplants. When such small regenerating nerve fibers become involved in scar tissue, cicatricial compression or microscopic neuromas occur and may lead to persistently painful scars.<sup>2, 3</sup> Figure 1 is a silver impregnation of a profuse neuromatous overgrowth after division of a small cutaneous nerve trunk in the rabbit.

Numerous methods have been devised in the attempt to prevent neuromas after division of larger nerve trunks. None of these are completely successful in all instances. For small cutaneous nerves, frequently not identified grossly at operation, no method of limiting undesirable nerve regeneration has been advanced. When the nerves can be seen during dissection, crushing with an hemostat proximal to a ligature of nonabsorbable material is indicated.

Simple excision of a scarred area containing a microscopic neuroma followed by primary healing does not often lead to a recurrence.<sup>3</sup> However,

subcutaneous nerve trunks the size of the supra-orbital and greater occipital nerves and their main branches are likely to regenerate. An effort should be made to find and treat the proximal stumps when these nerves are divided.

#### CONCLUSIONS

1. Some cases of localized headaches seem to originate in nerves supplying the scalp area.
2. When a definite lesion affecting the nerve is present, local surgical treatment is likely to be of benefit.
3. Injection or section of nerves without demonstrable lesions gives variable results.
4. Regeneration of divided scalp nerves may lead to recurrence of headaches.

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# OSTEOMYELITIS OF THE PETROUS PYRAMID OF THE TEMPORAL BONE

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SUPPURATION of the petrous pyramid was a frequent intermediary stage in the development of complications of middle ear infection in the years preceding sulfonamide and penicillin therapy. The nature of the process and the reason for its occurrence and persistence despite mastoid surgery promoted much investigation and the basis for clinical interpretation and surgical treatment was gradually established.

While chemotherapy has provided a valuable aid in the prevention and control of such infections and greatly reduced the necessity for surgical intervention its effectiveness has been subject to certain limitations. Experience has shown these drugs to be most effective in the invasive and early stages of middle ear infection. The presence of bone involvement such as breakdown of cell partitions, osteomyelitis, and sequestration tends to limit their effect to one of localization, while a cure is still dependent upon surgical drainage.

The anatomic arrangement of the temporal bone is such that osteomyelitis and sequestration are with only rare exceptions confined to the petrous portion. Because of its close relationship to important structures complications tend to develop early. Under conditions of partial drainage the suppuration may become chronic or with inhibition of the infection by chemotherapy it may appear to subside only to become active and invade the inner ear or meninges at a later date.

The pathogenesis of the process in the pyramid formerly provoked much debate. Suppuration of the mastoid was recognized to depend on pneumatization. Gross examination of the pathologic pyramid, however, seldom permitted the recognition of pneumatic spaces and suppuration of that area was usually thought to be purely an osteomyelitis. The relation of such an osteomyelitis to infection in air cells became apparent only when the temporal bones had been removed at autopsy, sectioned serially, and studied under the microscope. Such studies of pathologic as well as normal bones have shown that the behavior of the infection within the temporal bone is primarily dependent upon the anatomic arrangement. The variation in extent and course of the disease which had been difficult to explain proved to be dependent upon variations in extent of the air cell system.

## ANATOMIC CHARACTERISTICS

The petrous pyramid consists of an apical and a labyrinthine part. The apex lies medial to the labyrinthine capsule and the bony canal of the internal carotid artery and articulates with the basi-occiput and body

## OSTEOMYELITIS OF PETROUS PYRAMID

of the sphenoid bone. It contains marrow spaces filled in infancy with red marrow which later changes to the gray or fatty type.

The labyrinthine part of the pyramid lies between the apex and the air cell system of the middle ear and the mastoid. Marrow spaces are also present in this part in infancy and may persist throughout life. With the process of growth the pyramid enlarges by addition of periosteal bone to its surfaces. Marrow spaces expand into this new bone. As the layer of periosteal bone is thickened it becomes exposed to the forces exerted within the air cell system which produce pneumatization.

The tendency to pneumatize varies, depending probably on two factors: the amount of periosteal bone which is added to the pyramid; and the presence of normal eustachian tube function to provide free aeration.

The extent of the air cell system is of primary importance in the dissemination of infection. Petrous pyramids may be divided into two main groups: those without, and those with pneumatization. In the former group, which includes about two-thirds of adult bones, the system of air cells is limited to the mastoid with possible extensions into the zygomatic root and squama. In these, the labyrinthine capsule and the bony canal of the internal carotid artery form a natural barrier of dense bone between the marrow-containing apex of the pyramid and the air-containing middle ear and mastoid. In this group the contact between marrow spaces of the pyramid and the cell system is limited to small areas in front of or behind the superior semicircular canal. Invasion of these areas by infection does not occur; partly because their limited extent favors an adequate defense reaction, and also because the adjacent air cells drain freely to the middle ear (Fig. 1). The efficiency of this barrier is hereby illustrated in a case of middle ear suppuration in the presence of uncontrolled diabetes mellitus. In this case the reduced general resistance to infection undoubtedly predisposed to the relatively rare complication of osteomyelitis of the cranial vault as a direct extension from the mastoid cells. The marrow spaces of the apex were sufficiently protected, however, although small extensions lay adjacent to the cell system (Fig. 1) and showed an inflammatory response.

The mastoid air cells begin to form before birth and pneumatization keeps pace with growth of the bone<sup>4</sup>. Infection of the mastoid is, therefore, an infection of the air cell system rather than an osteomyelitis from infancy onward. Extension from the cell system to the marrow spaces of the squama or zygomatic root are rare, because erosion of the thin outer or **inner** cortex provides an easier exit for the suppurative process. Extension to the marrow spaces of the pyramid tends to be prevented in the infant by the labyrinthine capsule, but this natural barrier persists throughout life only in nonpneumatized pyramids.

Although invasion of the marrow spaces of the bones of the vault rarely occurs from the cell system, the reverse process takes place readily. A spreading osteomyelitis of the cranial vault easily invades the cell

system of the mastoid (Fig. 2) producing a diffuse suppuration of all middle ear air spaces. The extension of an osteomyelitis of the vault to the petrous pyramid is prevented by the interposed air cell system and the dense labyrinthine capsule. In those bones with pneumatization extending into the pyramid the comparative isolation of the apex from a middle ear infection no longer exists.

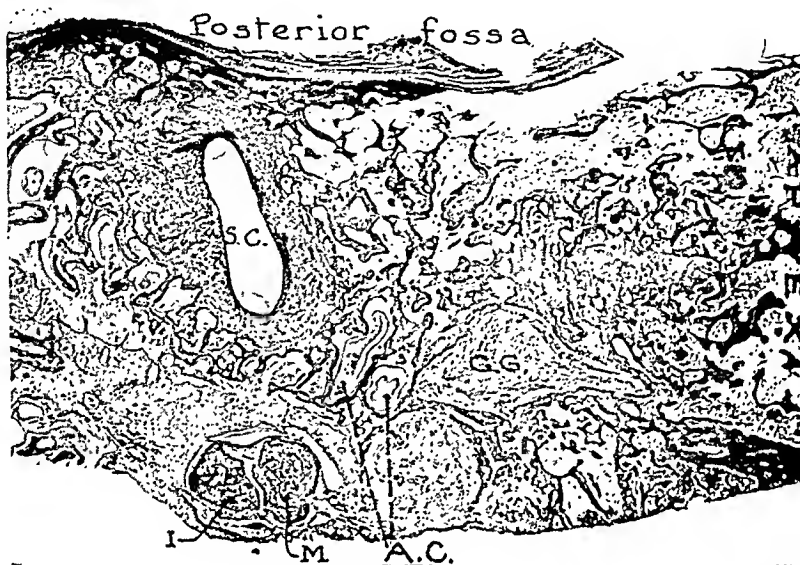


FIG. 1.—Case No. 1: Suppurative otitis media in uncontrolled diabetes mellitus in an adult. Direct extension to marrow spaces of the bones of the vault but not to the petrous pyramid.

Horizontal section through an upper level of the pyramid showing superior semicircular canal (S.C.), the geniculate ganglion (G.G.), the malleus (M) and incus (I). The air cells (A.C.) filled with exudate mark the beginning of pneumatization of the perilabyrinthine area. The inflammatory reaction and early fibrous tissue proliferation in adjacent marrow spaces has protected the apex from invasion.

#### PNEUMATIZATION

Extension of the cell system into the pyramid begins shortly after infancy and may be well developed by the fourth year<sup>2, 3, 4</sup>. It was found in one-third of all bones of four years of age and over on examination of serial microscopic sections<sup>5</sup>.

Since the periosteal layer of bone in which pneumatization occurs varies in its amount and location, and may occur mainly on either of the inferior, posterior or superior aspects, the cell tracts which develop vary correspondingly in their location. The most frequent site of pneumatization is the posterosuperior angle of the pyramid, medial to the superior semicircular canal where a large block of bone is deposited to fill out the subarcuate fossa after birth. This area is pneumatized from the epitympanum and mastoid. Air cells beneath the labyrinth develop either from the mastoid or hypotympanum<sup>5</sup>.

Relatively few marrow spaces may remain back of the labyrinth, but the air cells in that area may border freely on marrow spaces extending

# OSTEOMYELITIS OF PETROUS PYRAMID

from the apex. These perilabyrinthine air cells may be demonstrated roentgenographically on the Stenver's and occipital projections. The apex of the pyramid is pneumatized to some extent in over 20

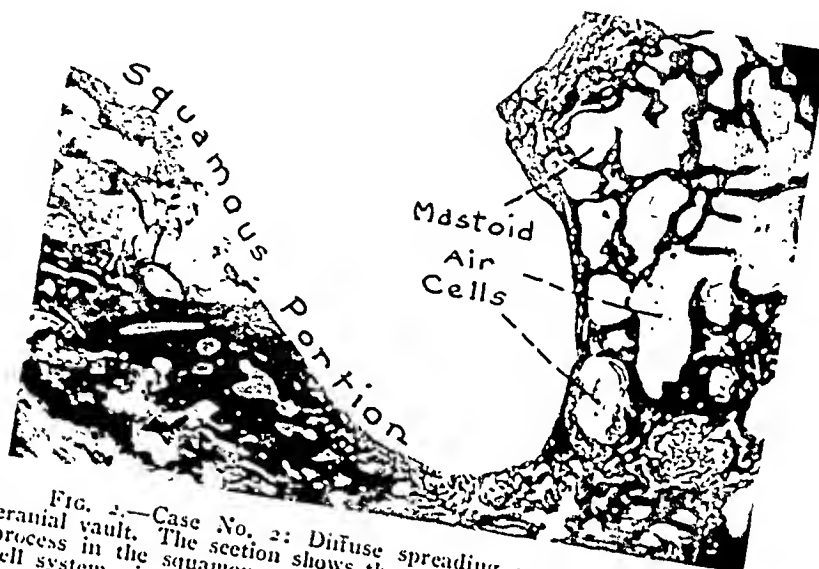


FIG. 2.—Case No. 2: Diffuse spreading osteomyelitis of the cranial vault. The section shows the extension of the osteomyelitic process in the squamous portion of the temporal bone to the air cell system of the ear.

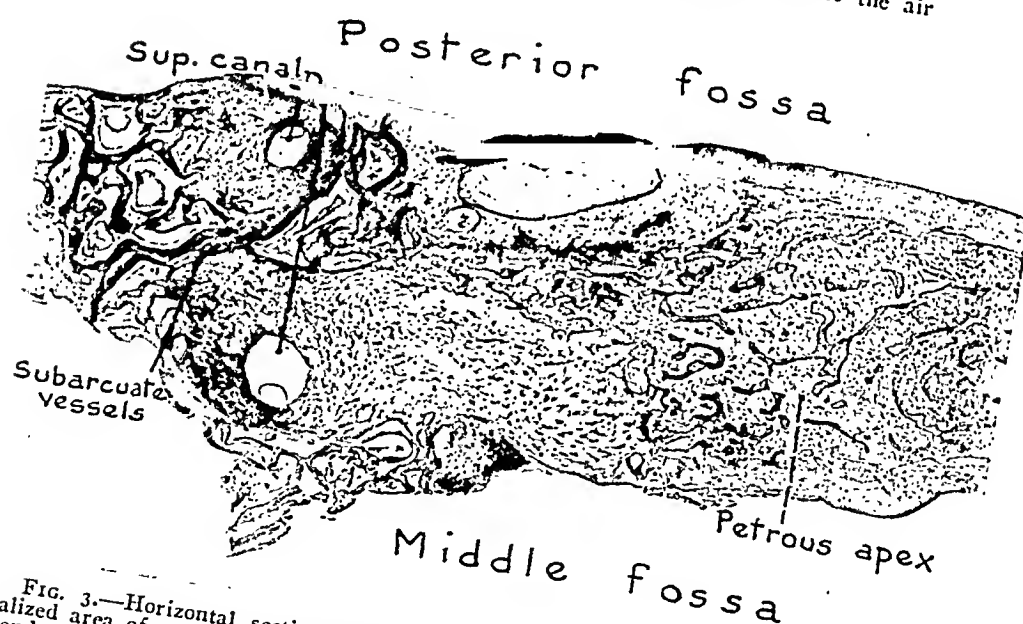


FIG. 3.—Horizontal section through the upper level of a petrous pyramid with a localized area of suppuration in the group of cells behind and above the labyrinth which extended through the cortex to the meninges. The marrow spaces of the apex show diffuse fibrosis and sclerosis. (Case reported in *Ann. Otol. Rhin. & Laryng.* 47: 3, 1938)

per cent of bones. The amount of marrow replaced by air cells varies, but is usually less than half. Only a single large cell may be present. This is in contrast to the apex of the monkey, where extensive pneumatization is the rule.

From a practical viewpoint a single cell may be as important as a

group of cells, since it provides a portal of entry for infection. The length and size of the channel or bottleneck through which pneumatization has developed has a greater influence on the course of the suppuration than the size of the pneumatized area.

The apex is pneumatized in two principal regions. In one group the



FIG. 4.—Roentgenogram of the skull in the transorbital projection made immediately after surgical drainage of the petrous apex. The end of the probe lies in the center of the suppurative focus. The apex was drained over three months after mastoidectomy. Recovery was rapid.

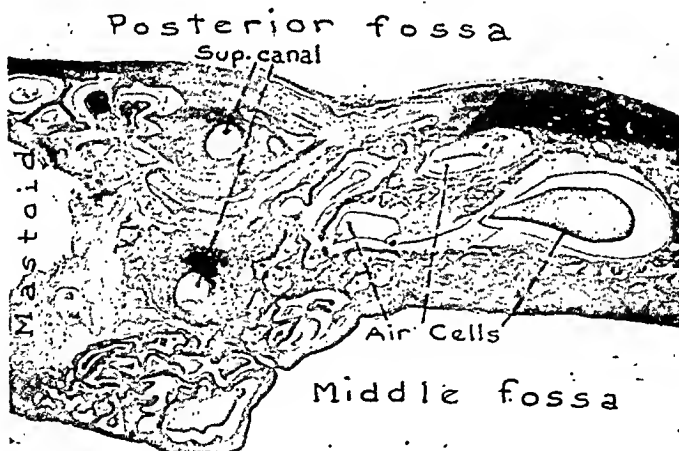


FIG. 5.—Case No. 3: Horizontal section through an upper level of the petrous pyramid showing the mastoid antrum, the superior semicircular canal, and the air cells in the apex filled with exudate. These air cells developed from the epitympanum and provided an entrance for infection. From them it extended to surrounding marrow spaces (See Figure 6) which at this level show chronic fibrosis and sclerosis.

air cells extend along the posterosuperior angle over the internal auditory meatus. This represents simply an extension of perilabyrinthine pneumatization and the cells lie in the upper half of the apex underneath the cortex of the middle fossa (Fig. 5). In the other group the cells have developed



from the tympanic cavity or peritubal cells in relation to the carotid artery, and lie mainly in the lower half of the apex.

The cells in the upper part of the apex are shown roentgenographically on the Stenver's and transorbital projections, while those in the lower half require an axial or mentovertical view.

The pathway of pneumatization provides the key to the interpretation of clinical and roentenologic findings and to the simplest route for surgical drainage.

#### ACUTE OSTEOMYELITIS

Invasion of the marrow spaces by infection may occur by several routes, but in the overwhelming majority it is a direct extension from the air cell system.

Hematogenous infection has occurred in severe puerperal infection and also from an osteomyelitis elsewhere in the body<sup>6</sup>. Such an osteomyelitis tends to spread to the air cell system.

Direct invasion of the apex from an osteomyelitis of the sphenoidal bone may occur<sup>7</sup> as well as the reverse process. Acute osteomyelitis has been observed also as part of a panotitis of meningitic origin in the late stages of meningitis.

Hematogenous invasion of the apex by tuberculous infection is common, particularly during a miliary dissemination,<sup>8</sup> and tends to involve the air cell system as well.

The common type of osteomyelitis of the pyramid is that in which the infection extends directly from the middle ear cell system along pneumatized tracts. Although the gross appearance has suggested invasion of the apex in nonpneumatized pyramids, the microscopic studies so far have consistently shown the presence of tracts of air cells leading in to the pyramid which permitted free entrance of the infection. The disease, therefore, appears to be a potential only in pneumatized pyramids.

The usual anatomic arrangement of such cell tracts is that the air cells broaden out as the tract reaches certain areas, notably the apex (Fig. 5) and the area in the angle behind the labyrinth. Since such air cells have no cilia to aid in their protection, but depend upon the circulation for mobilization of their defense, infection passes inward readily, but the resultant swelling of the mucoperiosteal lining membranes impedes drainage at the narrow points of exit. One and sometimes two bottle-necks must, therefore, be traversed by the purulent discharge in reaching the middle ear and external canal, thereby creating a tendency to obstruction of drainage.

The existence of adequate drainage has been a primary factor in the control of such infection. With the use of sulfonamides and penicillin in the invasive or early stages, such infections may now be controlled almost without exception; but after suppuration has become advanced, these drugs are less effective and adequate drainage continues to be essential for

recovery. Retention of suppuration within a pneumatized area leads to absorption and breakdown of the cell partitions with invasion of contiguous structures, the infection following the path of least resistance.

Suppuration in the group of cells behind and above the labyrinth with inadequate drainage tends to invade the middle or posterior cranial fossae. It may also cause erosion of the labyrinthine capsule and labyrinthitis. Sequestration of portions of the semicircular canals may occur in such cases<sup>9</sup>, probably as a result of destruction of blood supply of their narrow bony walls. Chronic suppuration frequently occurs, sometimes with a persistent postauricular fistula after mastoidectomy. The occurrence of osteomyelitis appears to depend on the proximity of the marrow spaces of the apex. In some there is little involvement and in others

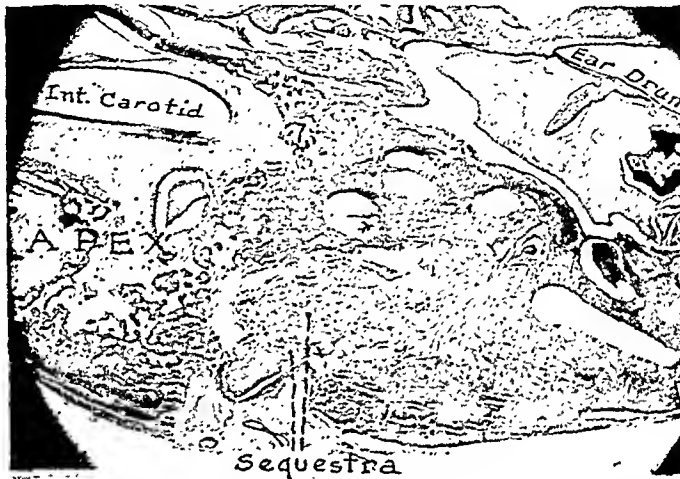


FIG. 6.—Case No. 3: Horizontal section through the midportion of the labyrinth, below the air cells shown in the apex in Figure 5.

Diffuse suppuration and necrosis involves the whole apex with several bony sequestra. The disease was localized by sulfadiazine therapy and remained quiescent for over a year but eventually destroyed the inner ear and invaded the meninges.

a localized invasion of adjacent marrow varying from a mild fibrosis to suppuration and necrosis. The tendency to produce diffuse osteomyelitis increases with the extent of the cell tract into the apex. The marrow possesses considerable capacity for resistance to infection and in some cases the cortex and meninges may be invaded while the marrow exhibits only a diffuse reactive fibrosis and sclerosis (Fig. 3). In others, irregular areas of necrosis develop and eventually the whole apex may be involved (Fig. 6). Such a suppurative focus constitutes a combination of broken-down air cells and marrow spaces. The suppuration shows a greater tendency to break through the bony cortex and invade the cranial cavity, the inner ear, or the neck than to extend as an osteomyelitis to the basi-occiput and sphenoid. Such a tendency may be due in part to the type of organism, which is usually an *hemolytic Streptococcus* or *Pneumococcus*, and seldom a *Staphylococcus*.

From a clinical viewpoint, the localizing tendency is of practical importance. The establishment of drainage during this stage is usually sufficient to effect a rapid cure. Suppuration which has been present as long as two and three months with extensive destruction of the apex may heal rapidly after surgical drainage (Fig. 4). Extension to the marrow spaces of the occiput and sphenoid may occur, however, and is indicated by clouding of the sphenoid sinus on roentgenologic examination, due either to thickening of its mucosa or suppuration. The osteomyelitis may spread to the opposite temporal bone and usually results in invasion of the meninges.

#### CHRONIC OSTEOMYELITIS

Suppuration in the perilabyrinthine part of the pyramid has frequently become chronic when not drained adequately, and frequently accounts for a persistent fistula after mastoidectomy and sometimes sequestration of parts of bony canals; but may not constitute an osteomyelitis. Suppuration of the apex may also become chronic and persist for years without complication. Localization of the source of discharge along with roentgenographic evidence of sclerosis may permit the diagnosis. Such suppuration is probably similar to that which occurs in the mastoid, involving air cells primarily with a reactive sclerosis of adjoining marrow spaces.

Since the development of sulfonamide therapy, a number of cases of chronic osteomyelitis of the apex have appeared which without these drugs would probably have succumbed in the acute stage to a complication. With chemotherapy the suppurative process has been localized. The course and fate of such a suppurative process varies and is influenced by such factors as the extent of the osteomyelitis and the degree of drainage. Sulfonamides in high concentration as well as penicillin therapy have sometimes failed to effect more than a temporary alleviation of the process.

This temporary localizing effect was demonstrated by the case illustrated in Figures 5 and 6. In this case the infection in the middle ear spaces due to the *hemolytic Streptococcus* gained access to the apex from the epitympanum along a pneumatized tract (Fig. 5), setting up a diffuse osteomyelitic process. The blood stream and inner ear were invaded. A thorough course of sulfadiazine together with mastoid exenteration was followed by an apparent cure and complete cessation of discharge. Fifteen months later, however, a fatal meningitis developed and on postmortem examination a chronic osteomyelitis of the apex was found with several large bony sequestra (Fig. 6).

In retrospect, it appears that the osteomyelitis was already established before the treatment was instituted. The recognition and successful surgical removal of the sequestra would scarcely have been possible, but simple surgical drainage of the apex along with chemotherapy might have obviated further complications.

An illustration of the combined effect of surgery and chemotherapy

in chronic osteomyelitis of the apex is afforded by the case illustrated in Figures 7 and 8, in which the disease has now been under observation and treatment for seven years. As in the previous case, the disease began as a unilateral middle ear infection due to the *hemolytic Streptococcus*. Invasion of the apex along a pneumatized tract was followed by cell breakdown and osteomyelitis. The inner ear was destroyed, the blood stream invaded, and an abscess formed in the neck. Following mastoid drainage and sulfanilamide therapy the acute symptoms subsided, leaving a chronic discharge from the middle ear and a fistula in the neck. The petrous apex was not drained surgically until one year later when meningitic signs appeared. Since that time osteomyelitis has spread by way of the basi-occiput and sphenoid to the opposite temporal bone, invading the middle ear air spaces and the labyrinth. Both petrous apices have been drained



FIG. 7.—Case No. 4: Chronic osteomyelitis of both petrous apices and the body of the sphenoid, seven years duration. Roentgenogram of the base of the skull in the axial or mento-vertical projection. In this case the progress of osteomyelitis could be traced from one petrous apex across the basi-occiput and sphenoid to the opposite temporal bone. Both apices have been drained surgically. This roentgenogram shows a silver probe in one apex at operation. Defects in the bone are visible in both apices and the body of the sphenoid.

surgically along with an extremely heavy course of sulfadiazine and later penicillin. This patient continues to have an active osteomyelitis (Fig. 7) and slight discharge from both ears and the neck fistula (Fig. 8), but is otherwise in apparent good health except for total deafness.

The survival of this patient must be credited to the combination of chemotherapy and surgery. Unfortunately, at the time each inner ear was invaded, the patient was not seen in time to permit surgical drainage of the apex before function had been destroyed.

Cases such as these two illustrate clearly the limitations of chemotherapy in the present form after an osteomyelitis has once been established. Surgical drainage must be considered as an essential part of the treatment in both the acute and chronic stages, if complications such as destruction

of the inner ear or invasion of the cranial cavity are to be avoided. In the presence of chronic osteomyelitis with possible sequestration or extension to other bones of the base of the skull, a combination of chemotherapy and surgical drainage may serve to keep the process localized but fail to effect a complete cure.

#### SUMMARY

1. The middle ear air spaces separate the marrow spaces of the bones of the vault from the petrous pyramid and other bones of the base of the skull.

2. Infection passes readily from marrow spaces to air cells, but extension in the reverse direction meets greater resistance. The cell system, therefore, tends to limit the spread of osteomyelitis between the vault and the base of the skull.

3. Osteomyelitis of the petrous pyramid sometimes occurs by the hematogenous route or by extension from other bones of the skull base, but is usually a direct extension from middle ear suppuration.

4. The dense labyrinthine capsule forms a barrier between the marrow-containing apex and the middle ear cell system in the majority of bones. In about 20 per cent of bones, however, the air cell system invades the apex, creating a direct entrance for infection and the possibility of osteomyelitis.

5. A tendency to obstruction of drainage created by natural bottle-neck predisposes to breakdown of cell partitions and invasion of surrounding marrow spaces in the apex.

6. Osteomyelitis tends to remain localized within the apex during the acute stages and responds well to surgical drainage.

7. Chemotherapy provides a valuable aid in localization, but cannot be depended upon to cure without surgical drainage.

8. In the presence of sequestration or extension of the osteomyelitis to other bones of the base of the skull, the combination of chemotherapy and surgical drainage offers a means of avoiding dangerous complications but may fail to eradicate the disease.



FIG. 8.—Case No. 4: Photograph showing the location of the fistula in the neck posterior to the sternocleidomastoid muscle. Purulent discharge with *hemolytic streptococcus* on culture persists from the fistula and from both ears.

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# THE PRESENT STATUS OF ETHYLENE-OXYGEN ANESTHESIA

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IT IS FITTING that a review of the present status of ethylene be made at this time. From the introduction of this anesthetic agent in humans in 1923, through 22 years of extensive clinical usage, Doctor Phemister has had intimate contact with ethylene.

In 1779, Priestley<sup>1</sup> referred to Ingenhousz as the first to generate ethylene. Likewise, in a Latin text (*Physica subterannea*) Becker is credited with first generating ethylene. The medical literature contains erroneous and confusing reports in regard to further investigations concerning ethylene during the next century.<sup>2</sup> In 1885, Luessem used an ethylene-oxygen mixture to produce unconsciousness in frogs, rabbits, a canary, two dogs and a guinea-pig, and then inhaled the gas himself, but not to the stage of unconsciousness.

Apparently, from 1885 to 1918, the only further investigations were in 1901, when Neljubow noted the effect of ethylene on etiolated seedlings, and, in 1908, when Crocker and Knight, of the Hull Botanical Laboratories of the University of Chicago, found that ethylene put carnations "to sleep."

In 1918, Luckhardt and Thompson,<sup>3</sup> working independently, and without knowledge of the work of Luessem and earlier investigators, established on frogs, rats and a dog both the anesthetizing and analgesic properties of a mixture of 80 per cent ethylene and 20 per cent oxygen. A report made by Brown,<sup>4</sup> in March, 1923, from work on mice, rabbits, cats and dogs, confirmed the results obtained by Luckhardt and Thompson.

At this time Luckhardt and Carter were establishing on themselves and others the analgesic and anesthetic properties of ethylene. On January 21, 1923, this agent was first demonstrated to a group of scientists at the University of Chicago.<sup>3</sup> J. B. Carter was the first human anesthetized with this gas. Doctor Phemister was the first surgeon to be anesthetized with ethylene, which event occurred on February 4, 1923. Surgical procedures under ethylene began on March 14, 1923, when Dr. Arthur Dean Bevan removed sebaceous tumors of the scalp from a patient at Presbyterian Hospital, Chicago. Dr. Isabella C. Herb was the anesthetist.<sup>5</sup> On April 27, 1923, Luckhardt and Carter reported the first 106 operations performed under ethylene at Presbyterian Hospital.<sup>6</sup>

Throughout the era of modern anesthesia, news of most new anesthetic agents spread rapidly, and soon thereafter many individuals have given these agents clinical trial. Although the next few years marked widespread use of ethylene, unfortunate newspaper publicity associated with a few explosions led to the discontinuation of its use in certain localities. Later developments have shown that the explosion potentiality of this agent is practically no

greater than that with nearly all of our inhalation agents, as will be discussed subsequently. With this additional fundamental physical knowledge, ethylene has continued to be popular in some localities, as is illustrated by such reports as 61,924 administrations at the Mayo Clinic<sup>7</sup>; and 35,500 at the Sayre Clinic.<sup>8</sup> That this agent has also aroused interest and use in foreign countries is evident from communications from Italy,<sup>9</sup> South America,<sup>10-13</sup> and Belgium,<sup>14</sup> among others.

It is the purpose of this communication to review the present physical, physiologic and pharmacologic knowledge of ethylene, and to evaluate clinical results with this agent.

Chemically, ethylene may be considered as dehydrated ethyl alcohol.  $C_2H_5OH$  plus heated  $H_3PO_4$  equals  $C_2H_4$  plus  $H_2O$ . Orthophosphoric acid was used as a decomposing agent when ethylene was first prepared by Luckhardt and Carter. Sulfuric acid has been used to dehydrate the alcohol. It may also be prepared by cracking propane. Ethylene is an unsaturated hydrocarbon gas, and adds halogen and acids. Compressed in steel cylinders, U.S.P. requirements are that a cylinder must contain not less than 99 per cent by volume of ethylene. Actually, some of the commercial products average 99.70 per cent pure ethylene (99.50 per cent minimum to 99.90 per cent). Impurities may be other hydrocarbons, such as propane, methane, or acetylene; carbon dioxide, nitrogen, hydrogen sulfide, aldehydes, phosphine, or traces of carbon monoxide. It is free from these impurities when marketed for anesthesia.

Physically, ethylene is a colorless gas with a sweet, musty odor which patients rarely find offensive. The odor varies according to the impurities in the gas. When properly made by the dehydration of alcohol it has a pleasant odor.<sup>15</sup> It is a nonirritating gas. Ethylene has a molecular weight of 28; specific gravity of 0.97; boils at  $-103^\circ C.$  and liquefies at  $10^\circ C.$  under 60 atmospheres. It has a flash point below  $32^\circ F.$

That the fire and explosion hazard is inherent in all inhalation anesthetic agents except nitrous oxide, and chloroform is well illustrated by Table I.

TABLE I  
LIMITS OF FLAMMABILITY OF ANESTHETIC GASES

Substance	Atmosphere	Flammability Limits Per Cent by Volume		Sp. Gr. (Air)
		Lower	Upper	
Ether*	Air	1.85	25.9	2.56
Ether†	Oxygen	2.1	82.0	
Ethyl chloride†	Air	4.0	14.8	2.23
Ethylene*	Air	3.05	28.6	0.97
Ethylene*	Oxygen	3.10	79.9	
Cyclopropane*	Air	2.45	10.45	1.45
Cyclopropane*	Oxygen	2.48	60.00	
Vinyl ether†	Oxygen	1.8	85.0	
Acetylene.....	Air	3.40	52.5	
Acetylene.....	Oxygen	3.40	90.0	

\* U. S. Bureau of Mines.

† Buchman and Wardell-Ohio Chemical Co. and Prof. Hoyt C. Hottel, Dept. of Chemical Engineering, Massachusetts Institute of Technology.



As emphasized in Table I, the fire and explosion hazard is markedly increased when oxygen is added to the anesthetic agent. Ethylene-oxygen in anesthetic mixtures usually can be administered in a range outside the flammable limits. This is not true of all inhalation agents, as can be seen in Table I.

Anyone employing ethylene should abide by the Report of the Committee on Anesthetic Accidents<sup>16</sup> and not use mixtures too rich in oxygen, since they stated that when the percentage of ethylene mixed with oxygen is about 25, with a considerable range above and below this percentage, the explosions are of detonating force. With still higher concentrations of ethylene in oxygen the force of the explosion decreases. At an upper limit of 80 per cent ethylene mixed with 20 per cent oxygen, explosibility ceases. Fortunately, this is a good anesthetic mixture and provides adequate oxygenation for most patients.

That the common practice of adding ether to nitrous oxide-oxygen makes a mixture which from a practical standpoint is equally dangerous, has been illustrated by explosions and deaths.<sup>17</sup> Greene,<sup>18</sup> in a clinical investigation of 230 cases of fires or explosions during anesthesia, stated that ether-oxygen, with or without nitrous oxide, has the same tendency toward propagating a wave of flame or pressure through the respiratory tract, as have ethylene-oxygen or cyclopropane-oxygen when compared under similar clinical circumstances, *i.e.*, the location of the point of ignition with reference to the respiratory tract of the patient.

Since explosions are statistically today one of the least of the hazards of anesthesia, they should not deter us from the use of any of these valuable agents, but instead only emphasize the need for the medical profession to have knowledge of anesthetic combustion, and act accordingly during the employment of these agents, to ensure their safe usage.

Among widely accepted practices that should be followed in the use of all explosive anesthetic agents are methods to eliminate static sparks, which are responsible for the greatest number of explosions. These include:

- a. Wetting the mask, tubing, hands and breathing bag (if possible) immediately before the mask is applied.
- b. Do not have the gas flowing at the time the mask is applied or lifted.
- c. Keep the anesthetist's hand in contact with the patient's face and mask at all times when the gas is flowing.
- d. No cautery or sparking device should be employed.
- e. Maintenance of a relative humidity of 60 per cent, or above, in all operating rooms.
- f. The Horton intercoupler or some other method of adequately grounding patient, operating table and anesthetist seems advisable.

#### PHYSIOLOGIC AND PHARMACOLOGIC EFFECTS

Induction of anesthesia with ethylene-oxygen is rapid and pleasant. An excitement stage seldom occurs.<sup>2</sup> There is no increase in mucus secretions

and no irritation of the pulmonary endothelium.<sup>19</sup> Respirations may be increased or slightly irregular during induction, but are normal during first and second plane of surgical anesthesia.

Spectroscopic examination revealed that apparently ethylene does not enter into chemical combination with the hemoglobin of the blood.<sup>3</sup> It is believed to exist in the blood in a state of physical solution, which may explain the rapid recovery period. The solubility of ethylene in blood varies with its water and lipoid content.<sup>20</sup> Nicloux and Yovanovitch<sup>21</sup> found that 70 to 80 per cent of the ethylene present in whole blood is in the cellular elements and the remainder in the plasma. They could detect only traces of ethylene in the arterial blood two minutes after administration was discontinued. Perhaps their analytic methods may not have been very sensitive. Seevers, DeFazio and Evans,<sup>22</sup> from analysis of intraperitoneal and subcutaneous gas pockets in rabbits, and dogs, concluded that both ethylene and cyclopropane were present in tissues many hours after the animal had apparently recovered from anesthesia. Nitrous oxide diffused through the human skin 20 times as rapidly as ethylene.<sup>23</sup>

Ethylene had little effect on the osmotic resistance and fragility of red cells to hypotonic saline, while ether or chloroform caused a marked reduction in the osmotic resistance of the red cells.<sup>24</sup>

The color of the blood should always be kept normal, and no evidence of anoxia be permitted. As with any of our anesthetic agents, the range of anesthesia for man varies considerably with the individual. That ethylene-oxygen can give second plane surgical anesthesia in many individuals without producing anoxia has been previously reported.<sup>25</sup> Our knowledge of the effects of specific concentrations of ethylene-oxygen is based upon arterial blood oxygen determinations made simultaneously with intratracheal, and breathing bag analyses, compared with the gas machine readings.

Relaxation with ethylene-oxygen is only moderate. It is usually adequate for everything except intra-abdominal work. It must be remembered that further decrease in the amount of oxygen in the anesthetic mixture gives lessened muscular relaxation because of the introduction of the mechanism of asphyxia. This asphyxia is manifested early in the eye. During first plane surgical anesthesia the lid reflex is rapidly obliterated but the activity of the eyeball muscles is present and a lateral oscillation is noted. In second plane surgical anesthesia the eyeball remains in the centric position indicating that the extra-ocular muscles are paralyzed and flaccid. This is aided by adequate premedication. In acute asphyxia the eyeball assumes an extremely eccentric and fixed position, either upward, or downward, or lateral. The pupil also dilates, the amount of dilatation depending upon the amount and kind of premedication used. This is due to the paralyzing effect of anoxia upon the iris muscle as well as other muscles. These manifestations are not due to the anesthetic agent *per se*, but to the asphyxia. Cyanosis is usually present with these manifestations of asphyxia, unless severe anemia or jaundice is present.

Death with ethylene is due to asphyxia. In dogs the respiratory center fails first. Heart action at the same time is quite normal and if artificial respiration is started at once the animal will recover promptly.<sup>2</sup> These same manifestations have been observed in humans.

During induction of anesthesia with ethylene there is no spasm due to direct irritation. According to Guedel,<sup>26</sup> the relative frequency of the occurrence of such spasm is seen with other inhalation agents, in the following order: ether, chloroform, ethyl chloride, divinyl oxide and cyclopropane. There is no tendency to increased laryngeal, bronchiolar, cardio-aortic or vagovagal reflexes, or any effect on cardiac automaticity as is observed in certain patients under cyclopropane anesthesia.<sup>27</sup> Reflex laryngospasm may occasionally be initiated by the stimulation of sensitive regions, such as periosteum, peritoneum or direct trauma to nerve trunks. It is of rare occurrence in orthopedic surgery. It is occasionally seen in chest surgery during stripping of the periosteum. It is then of brief duration, and ceases without producing ill effect as soon as the stimulus is removed. This sensitivity is decreased with adequate premedication.

Caine and Reynolds<sup>28</sup> reported that electrocardiographic studies made in dogs and cats during ethylene anesthesia gave no evidence of disturbance in cardiac automaticity or conduction. Kurtz, Bennett and Shapiro<sup>29</sup> found that procaine or ethylene are the anesthetic agents giving the lowest incidence of arrhythmias in humans. Ethylene gives no marked stimulation or depression of the vagus center.<sup>3</sup> The heart rate may increase slightly during induction if excitement is present, but cardiac action remains clinically normal during maintenance. Blood pressure usually remains normal, or only slightly elevated, after an initial rise which may be seen during the rare occurrence of excitement.<sup>30</sup> Killian<sup>31</sup> found no change in the EKG, and a stable pulse and blood pressure under ethylene anesthesia. Both the vasomotor and respiratory centers are not affected if the gas is administered properly without hypoxia. Ethylene is not a stimulant of the parasympathetic system.

The study of blood changes under any anesthetic is dependent upon the amount of oxygen in the circulation. Therefore, all anesthetic agents should be administered without cyanosis, labored or depressed respiration, or other evidence of hypoxia.

From results obtained both in dogs and humans, Trout<sup>32</sup> concluded that ethylene-oxygen produces less alteration of the percentage of blood sugar, no appreciable change in either the coagulation time or the bleeding time, and only a slight disturbance of the native complement when compared with ether, chloroform, nitrous oxide-oxygen and regional (sacral) anesthesia. Leake and Hertzman<sup>33</sup> found that when there is no anoxemia, ethylene does not lower the  $p_{H}$  and carbon dioxide content of arterial blood beyond normal limits, while ether or chloroform cause a marked and rapid change. Lemann,<sup>34</sup> from a study made upon diabetics who had undergone major surgery, pre-

ferred ethylene, which at no time gave any occasion for anxiety due to the anesthetic.

Brumbaugh<sup>35</sup> concluded from a study of 15 humans that ethylene-oxygen caused no change in the hemoglobin, coagulation time or character of the blood clot; only slight temporary decrease of the carbon dioxide combining power of the blood; the blood sugar although immediately increased, very quickly returned to the preanesthetic level; no immediate increase in blood urea, and only a slight increase in 24 hours; and contrary to the observations of Yates and Raine<sup>36</sup> found no appreciable change in the icterus index, or derangement of the biliary system.

The results of Yates and Raine,<sup>36</sup> and also Oberhelman and Dyniewicz,<sup>30</sup> agreed with the acid-base balance observations of Leake and Hertzman.<sup>33</sup> Oberhelman, *et al.*, reported that the changes in the nonprotein nitrogen constituents of the blood were insignificant and within normal variations.

Ethylene has less toxic effect on the kidney parenchyma than has ether.<sup>37</sup> Asphyxia of even normal kidneys for short periods of time leads to more or less disturbance of kidney function. Therefore, this is another reason why the asphyxia which is an inherent hazard of all anesthetic agents and methods must be avoided. Brumbaugh<sup>35</sup> found on chemical and microscopic study that the urine was normal after ethylene-oxygen anesthesia. Walton<sup>38</sup> observed that ethylene did not affect significantly the chloride, urea, and phosphorus output, or dye excretion and water diuresis in dogs, and concluded that there was no appreciable decrease in the 24-hour urinary output.

Stander<sup>39</sup> reported that ethylene produced no demonstrable lesions in the kidney. He also stated that anoxemia alone caused degenerative changes in liver cells.

Histologic examinations of body tissues after repeated administrations of ethylene over long periods of time were made by Bouchaert,<sup>40</sup> Franken and Miklós.<sup>41</sup> No more than a slight amount of congestion or fatty change in the parenchymatous tissue could be found. It is generally believed that, in the absence of anoxia, ethylene has little significant effect on general metabolic activity. Prothrombin deficiency does not appear in the normal dog following ethylene anesthesia.<sup>42</sup> Reynolds<sup>43</sup> observed no significant pathology on microscopic examination of kidneys, adrenals, hearts and lungs of white mice that had been repeatedly exposed to ethylene.

While ether and chloroform anesthesia in dogs gave complete inhibition of the contractions of the stomach, small intestines and colon, during which there was a distinct lowering of muscular tone, Miller and Plant<sup>44</sup> found that light ethylene anesthesia caused an increase in the amplitude of the contractions, without change in tone in the same viscera. In deep ethylene anesthesia, or after the removal of the anesthetic, the contractions decreased or rapidly returned to normal.

Johnson and Ivy<sup>45</sup> reported that ethylene depressed gastric secretion in man, but not to the same extent as ether. It also delayed the emptying time of the stomach.

CLINICAL EXPERIENCE

Ethylene has been employed in this institution during 18,250 operations. Ethylene-oxygen alone has been the anesthetic in 11,560 instances. Table II

TABLE II

Ethylene-oxygen.....	11,591
Ethylene-oxygen-ether.....	4,720
Nitrous oxide-oxygen to ethylene-oxygen.....	238
Local plus ethylene-oxygen.....	483
Spinal plus ethylene-oxygen.....	792
Continuous spinal plus ethylene-oxygen.....	33
Spinal plus ethylene-oxygen-ether.....	19
Avertin plus ethylene-oxygen.....	288
Avertin plus ethylene-oxygen-ether.....	21
Vinethene to ethylene-oxygen.....	5
Cyclopropane-oxygen to ethylene-oxygen.....	9
Ethylene-oxygen to cyclopropane-oxygen plus ether.....	9
Ethylene-oxygen plus intocostin.....	2
Splanchnic block plus ethylene-oxygen.....	38
Pentothal plus ethylene-oxygen.....	2
	<hr/>
	18,250

illustrates the frequency of the use of ethylene with other agents. Although ethylene combines satisfactorily with other anesthetic agents, a study of such a combination makes for confusion in attempting the evaluation of any one agent. For that reason, a detailed study has been made of only the patients who received ethylene-oxygen alone. The data herein presented concerns the last 3,210 consecutive patients where ethylene-oxygen alone was employed. The results obtained in this series are comparable to our previous experience.

There were no fires or explosions in the entire series of 18,250 anesthetics.

ETHYLENE-OXYGEN ALONE

There were no anesthetic deaths in our series. The very low incidence of anesthetic deaths with ethylene is illustrated by reports from Henson,<sup>46</sup> which appears in Table III. This includes the anesthetics given in 38 New York City hospitals during a four-year period. In a later report he<sup>47</sup> stated that ethylene seems to be unquestionably the best of the anesthetics in present use, and that the use and application of this fact would save many lives.

TABLE III

ANESTHETIC DEATHS IN OPERATING ROOMS—NEW YORK CITY

Four-year Survey (1937)

Agent	No. of Anesthetics	Deaths Per 100,000
Ether.....	513,560	15
Nitrous oxide.....	188,820	13
Cyclopropane.....	12,707	15
Ethylene.....	31,426	0
Chloroform.....	3,842	25
Ethyl chloride.....	810	493
Spinal.....	91,263	42
Local.....	146,976	11

Since this is a teaching institution, our series of anesthetics has been administered by a large number of inexperienced anesthetists working under supervision. The group of 3,210 ethylene-oxygen anesthetics being analyzed were administered by 91 physicians, including teaching personnel, anesthesia residents, and rotating surgical interns in addition to a large number of junior and senior medical students. This fact must be considered in evaluating the results.

TABLE IV  
OPERATIONS UNDER ETHYLENE-OXYGEN ALONE

Head—Intracranial.....	16
Head—Others.....	128
Neck—Thyroids.....	200
Neck—Others.....	152
Chest—Superficial.....	184
Radical mastectomy.....	139
Operations upon thoracic cage.....	29
Lung abscess, empyema, thoracostomy.....	40
Thoracoplasty or plumbage.....	191
Intrathoracic (heart, lung, mediastinum, esophagus).....	141
Abdomen—Superficial.....	57
Intra-abdominal (upper).....	33
Repair ventral hernia.....	17
Intestinal resection.....	24
Closure of colostomy.....	11
Appendicectomy.....	23
Inguinal or femoral herniotomy.....	59
Intra-abdominal gynecology.....	11
Miscellaneous anal and perineal.....	227
Operations upon adrenals.....	5
Bladder and ureter.....	10
Suprapubic prostatectomy.....	4
External genitalia.....	48
Perineph. abscess and miscellaneous lumbar.....	20
Nephrectomy.....	52
Nephrostomy and nephropexy.....	33
Bones, joints and tendons.....	1325
Nerves.....	31
Total.....	3210

This group was composed of 1,503 male and 1,707 female patients. Their age variation was:

1- 9 years = 101	30-39 years = 573	60-69 years = 239
10-19 years = 645	40-49 years = 543	70-79 years = 74
20-29 years = 603	50-59 years = 422	80-99 years = 10

*Premedication:* It is necessary to lower the metabolic rate with premedication to increase the potency of the gas and still maintain adequate oxygen in the blood. Apprehension should also be prevented.

Under ordinary circumstances atropine has no place in ethylene anesthesia, since it is not irritating to either the mucous membranes or the cardiovascular activity.

Morphine sulfate Gm. 0.010 to 0.015 hypodermically, and calcium nembutal Gm. 0.18 to 0.27 in 50 cc. of water per rectum, both administered one

## ETHYLENE-OXYGEN ANESTHESIA

to 1.5 hours before anesthesia were found to be very satisfactory for adults. The barbiturate prevented apprehension yet rarely caused confusion or depressed respiration. This, no doubt, contributed greatly to a smooth induction. A wide variety of other types of premedication were occasionally employed.

Table IV presents the type of surgery in which ethylene-oxygen alone was used.

Table V presents in detail the 50 deaths that occurred following the 3,210 operations, making a mortality rate of 1.5 per cent. There were no deaths in the operating room. It is of interest that the preoperative risk on the 50 patients was recorded as follows: Good, one; fair, seven; poor, 19; serious, 16; emergency (poor), six; semimoribund, one. The cause of death in most instances was determined at autopsy. Very few, if any, of the deaths were related to the anesthesia. The 13 deaths following thoracic surgery were considered by the surgeons to be adequately explained on the basis of the severity of the disease, and/or, the surgical procedure. Likewise, all the deaths from uremia were in patients who had uremia before anesthesia.

Very major surgical operations were performed under ethylene-oxygen anesthesia. In this series were 141 intrathoracic operations upon the heart, lung, mediastinum and esophagus. This includes the first successful resection of the lower esophagus and esophagogastrostomy for carcinoma performed through the thorax. This was made on January 26, 1938, by Dr. D. B. J. Post. The patient was a 53-year-old female, in fair preoperative condition. An uneventful ethylene-oxygen mask anesthesia was administered by Dr. G. Light, with a positive pressure type of anesthesia apparatus. Chart 1 illustrates the satisfactory postoperative course. The patient is without evidence of recurrence at the present time.

In order to evaluate the use of ethylene-oxygen in a group of patients who are poor surgical risks, a study of 191 thoracoplasties was made. One hundred and five male and 86 female patients comprised this group. The age variation was: one to nine years, one; ten to 19, seven; 20 to 29, 48; 30 to 39, 87; 40 to 49, 32; 50 to 59, nine, and 60 to 69, seven. The preoperative risk was: Fair 72; poor, 81; serious, 37; and special, one. Table VI presents the postoperative complications that occurred. The circulatory complications were not related to anesthesia. The 27 instances of postoperative oxygen want were explained by the extensive collapse made by the surgical procedure. The 12.5 per cent incidence of postoperative nausea and vomiting occurred in 20 of the 25 instances only on the day of operation and was no doubt due both to anesthesia and morphine. Four patients (2 per cent) had retention or cystitis. The same number were given too much postoperative sedation with respiratory-depressing drugs. The minor respiratory complications included three hiccup and six cough. One accidental pneumothorax and two instances of pleural effusion were surgical complications. One contralateral spread of pulmonary tuberculosis may have been due to both anesthesia





and surgery. The one instance of bronchopneumonia occurred over two weeks after anesthesia. The high fever was explained on the basis of the disease.

TABLE VI

191 THORACOPLASTIES—POSTOPERATIVE COMPLICATIONS

Complication	Total No.	Per Cent	Op. Day	Time				
				1-3 Days	4-7 Days	7-14 Days	14-21 Days	Within 1 Month
B.P. fall marked (not shock)...	3	1.5	2		1			
Traumatic shock.....	6	3.0	6					
Tachycardia.....	3	1.5		3				
Fibrillation.....	1	.5		1				
Transfusion reaction.....	1	.5			1			
Moderate secondary anemia..	2	1.0		1		1		
Overdose postop. depressing drugs.....	4	2.0		4				
Oxygen-want moderate.....	22	11.0	13	8				1
Oxygen-want severe.....	5	2.5	2	1	1		1	
Hiccough.....	3	1.5	1		1	1		
Cough.....	6	3.0	3			2	1	
Pleural effusion.....	2	1.0				2		
Accidental pneumothorax...	1	.5		1				
Contralateral pul. tbc.....	1	.5			1			
Bronchopneumonia .....	1	.5					1	
Nausea and vomiting.....	25	12.5	20	4	1			
Diaphoresis.....	1	.5		1				
High fever.....	16	8.0	3	10	1	1	1	
Debility.....	2	1.0			1	1		
Psychosis.....	2	1.0				2		
Headache.....	1	0.5		1				
Positional neuritis.....	1	0.5		1				
Retention or cystitis.....	4	2.0		2	1	1		
Moderate wound infection...	6	3.0			1	4	1	
Severe wound infection.....	1	0.5						1

Since pulmonary tuberculosis was a definite factor in evaluating post-operative complications another group containing many poor risk patients not having tuberculosis was studied. This included 200 thyroidectomies performed upon 35 male and 165 female patients with mask anesthesia. The preoperative risks were: Good, 79; fair, 81; poor, 30; serious, eight; and special, two. The age variation was: Ten to 19 years, six; 20 to 29 years, 36; 30 to 39 years, 47; 40 to 49 years, 61; 50 to 59 years, 36; 60 to 69 years, nine; and 70 to 79 years, five.

The complications during and following anesthesia appear in Table VII.

A notably low incidence of circulatory and respiratory complications occurred in these patients, many of whom had preoperative cardiovascular disease and underwent surgery which has inherent possibilities of interference with, or damage to, the respiratory passages.

In order to eliminate the factor of surgical interference with respiration, the 139 radical mastectomies were reviewed. The preoperative risks were: Good, 65; fair, 56; poor, 14, and serious, four. The age distribution was:

Twenty to 29 years, two; 30 to 39 years, 20; 40 to 49 years, 44; 50 to 59 years, 37; 60 to 69 years, 23; 70 to 79 years, 12; and over 80 years of age, one. Table VIII presents the incidence of complications during and follow-

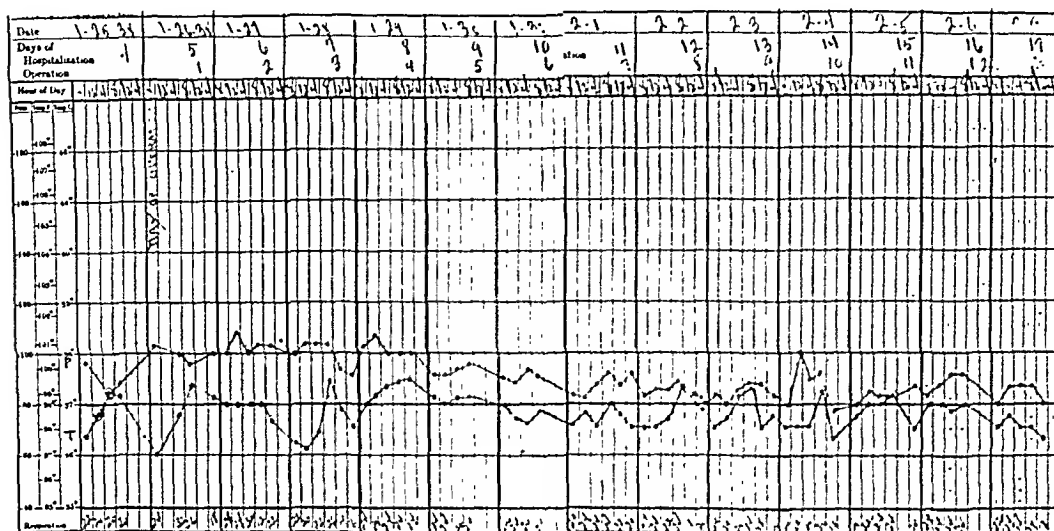


CHART I.—Showing postoperative course.

TABLE VII

200 THYROIDECTOMIES—COMPLICATIONS

During Anesthesia			Postoperative		
	Number	Per Cent		Number	Per Cent
Hypertension.....	8	4.0	Coronary.....	1	.5
Moderate hemorrhage.....	3	1.5	Moderate hemorrhage.....	5	2.5
Traumatic shock.....	1	.5	Circulatory failure.....	1	.5
Hypotension.....	1	.5	Fibrillation.....	6	3.0
Bradycardia.....	1	.5	Tachycardia.....	3	1.5
Tachycardia.....	6	3.0	Thyroid crisis.....	1	.5
Fibrillation.....	1	.5	Cystitis.....	1	.5
Nausea or emesis.....	9	4.5	Nausea and emesis.....	26	13.0
Cough.....	6	3.0	Diarrhea.....	1	.5
Moderate oxygen-want.....	6	3.0	Moderate oxygen-want.....	1	.5
Severe oxygen-want.....	2	1.0	Respiratory depression.....	1	.5
Moderate stridor.....	2	1.0	Cord paralysis.....	1	.5
Tracheal compression.....	1	.5	Upper respiratory infection....	1	.5
Diaphoresis.....	3	1.5	High fever.....	11	5.5
Insufficient premedication....	6	3.0	Trauma to eye or skin.....	2	1.0
			Headache.....	2	1.0
			Cerebral embolus; thrombosis..	2	1.0

ing surgery, which indicates a very low morbidity rate from anesthesia. There may be some direct stimulation of the vomiting center by ethylene, but this occurred no more frequently than with nitrous oxide or cyclopropane, and it was minimal in comparison with ether. Prolonged nausea and emesis after ethylene was rare. A great deal depended upon the amount of morphine the patients received.

SUMMARY

Laboratory and clinical results indicate that ethylene-oxygen seems to be definitely the preferable inhalation agent for the poor-risk patient, including those with disturbed cardiopulmonary mechanisms. The reported death rate with ethylene is apparently lower than with any other inhalation agent.

Ethylene is deficient in providing deep abdominal relaxation for the average patient. It has the same inherent explosive quality that is present in all inhalation agents except chloroform or nitrous oxide.

Clinical experience inclines the author to believe, with Poe,<sup>48</sup> that we

TABLE VIII  
139 RADICAL MASTECTOMIES—COMPLICATIONS

During Anesthesia			Postoperative		
	Number	Per Cent		Number	Per Cent
Insufficient premedication....	4	2.8	Idiosyncrasy narcotic.....	1	.7
Bradycardia.....	2	1.4	Arrhythmia.....	1	.7
B.P. fall marked (not shock)..	9	6.3	B.P. fall marked (not shock)..	1	.7
Traumatic shock.....	3	2.1	Traumatic shock.....	1	.7
Moderate hemorrhage.....	1	.7	Moderate hemorrhage.....	1	.7
Hypertension.....	3	2.1	Transfusion reaction.....	2	1.4
Respiratory depression.....	5	3.5	Respiratory depression.....	2	1.4
Moderate oxygen-want.....	1	.7	Phlebitis.....	2	1.4
Respiratory obstruction.....	1	.7	Retention.....	1	.7
Cough.....	2	1.4	High fever.....	5	3.5
Nausea.....	7	4.9	Nausea.....	2	1.4
Emesis.....	5	3.5	Emesis.....	25	17.5
Diaphoresis.....	5	3.5	Chronic tonsillitis.....	1	.7
			Moderate wound infection....	5	3.5

should give our patients the advantages and safety of this superior anesthetic, and that it merits more widespread employment, particularly for many operations in the patients classed as "poor surgical risks."

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## ACOUSTIC TRAUMA

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ONE may think of trauma as due only to direct contact between the primary force and some part of the body. However, it may be pointed out that the force may originate at some distance and be propagated to the body like a sound wave through the surrounding medium (air, water). An important example is the blast wave.

The peripheral ear is a mechanism especially constructed to respond to pressure (sound) waves propagated by the molecules of the air at the rate of about 1,100 feet per second. The normal stimulus for the ear represents an exceedingly small pressure disturbance. When these pressure waves are sufficiently great they may traumatize the exquisitely delicate neural elements suspended in the fluid of the labyrinth.

Acoustic trauma (boiler maker's deafness, explosion deafness, *etc.*) is a term used here to denote injury to the neural elements of the ear by noise. The war has aroused general interest in this cause of deafness, because so many people are exposed to the great noises associated with modern warfare.

Noise has been an uncontrollable by-product of modern industrial civilization and modern warfare. While we have known in a general way for the past 100 years that noise is harmful to the ear, it is only during the last decade that any real progress was made in recognizing this kind of deafness and devising means for preventing it.

This report deals only with the effect of noise on the auditory sense but it is well to point out that many other harmful effects of noise have been observed, such as the effect on working efficiency, mental function,<sup>1</sup> *etc.*

The audiometer has been a great help in the study of this as well as other otologic problems. With the audiometer one can measure and record quantitatively in decibels the hearing acuity for just audible sounds over a wide range of frequencies. The widespread use of the audiometer soon brought to light many cases of hearing loss not suspected by the subject. One type of hearing loss was characterized by an abrupt high tone drop in the threshold curve or by an isolated drop around 4,096 cycles per second. Careful investigation often indicated that the subjects had been exposed to loud noise. Audiometric examinations of large numbers of people known to have been exposed in this way, were made recently by Bunch,<sup>2</sup> Larsen,<sup>3</sup> Rosenblith,<sup>4</sup> and others. These studies help to establish firmly the relationship between this early defect in hearing and excessive stimulation.

Noise may be defined as the sound sensation due to acoustic waves occurring at random intensity and frequency. In contrast, pleasing sound sensation is due to regularly recurring acoustic pressure waves. It is rare that the latter are sufficiently intense to cause deafness.

The analysis of noise is facilitated by modern acoustic, electronic instruments such as the wave analyzer, improved microphones, noise level meter, *etc.* A measure of the intensity and frequency of the component sounds in a particular noise is often made possible with such tools. Some difficulty remains in recording very brief acoustic pressure waves—such explosive noise as may be described as a pop, bang or crack, *etc.* The major disturbance may last only about 1/1000 of a second in these noises and it is difficult to devise apparatus that will faithfully follow such rapid phenomena (Fig. 1).

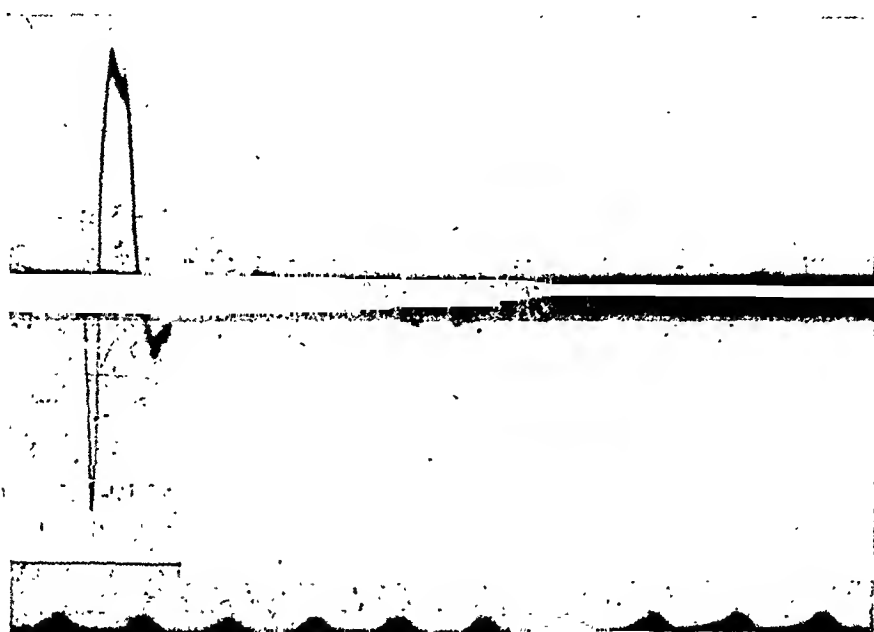


FIG. 1.—Record of movement of the human middle ear mechanism (at the malleus) to explosive noise. Note that major reaction is over in 1/1000 second. T is a 1000 cycle per second timing wave.

Clinical experience has indicated some of the noises that are harmful to the ear, *i.e.*, the noise of pneumatic hammers such as those used in rivetting and chipping steel, noise of various kinds of motors and turbines, noise of metal stamping machines, drop forges, and the noises from discharging firearms, and explosions of various kinds. Single shocks to the ear as from a telephone or from a blow on the ear can also damage the end-organ.

Many occupations are known to be associated with impaired hearing, *i. e.*, boiler makers, steel workers of other kinds, aviators, machinists, engineers, *etc.* While many industrial operations are exceedingly noisy, few studies have been made in the factory because of the fear of employers that medicolegal suits may follow. The problem has been recognized by some legal bodies and rates of disability and compensation have been worked out that are based on the results of the audiometric examination. The most important use we make of our auditory sense is for understanding speech. The frequencies tested for in the audiometric examination vary greatly in their importance for hearing the human voice. Tests show that we can hear sounds varying in frequency from 20 to 20,000 cycles per second. It is exceedingly important

for speech perception to hear well through the frequency range between 500 and 2,000 cycles per second. Considerable deafness above or below this range will have very little effect on our ability to understand speech. The ear is more sensitive through this range of sound in many different ways. The intensity needed to elicit a threshold response is much less than at a lower or higher range. Also through this frequency range we recognize more differences in loudness and in pitch as the intensity and frequency of the sound is changed. Another property of the auditory sense may be mentioned: That is the ability of the cortex to fill in gaps in the auditory spectrum. Controlled experiments show that only a narrow band of frequencies through this range is needed to understand speech. A familiar example of this cortical phenomenon is the ability to hear speech over a very poor telephone system—where most of the acoustic energy of a speaker at the other end of the line may not reach the listener—and only a narrow band around 1,000 cycles per second may reach the ear. Intelligibility is not greatly affected in spite of this distorted acoustic spectrum. The threshold curve obtained with the audiometer really measures only the capacity to hear. The cortex may compensate for considerable peripheral defect. Furthermore, people vary greatly in their demands on the auditory sense, *i.e.*, a musician is much more demanding than a laborer. Consequently, the clinician cannot predict the amount of complaint by looking at the audiogram alone. It is also important to understand that speech is carried out ordinarily at an intensity of 40 to 60 decibels above threshold. With ordinary acuity, one can understand a low conversational voice easily at some distance from the speaker even against the background of considerable noise. Even when the threshold curve indicates a loss of 10 to 25 decibels, not too much handicap results, because the listener will ordinarily be close enough to the speaker to receive a sufficiently intense stimulus from an average speaker. As the threshold curve drops to 30 decibels, and below, the ability to converse is much more affected because the speaker must now be less than three feet from the ear of the listener to deliver adequately strong stimuli—while using a moderate voice. It is impractical to carry on conversation at such close range or at a greater speech intensity. A small change in the hearing ability after it has dropped to the 30 decibel level, will, therefore, be very noticeable to the patient in his ability to converse with others.

With this general background of the auditory sense one may proceed to consider some of the factors involved in the deafness due to acoustic trauma. In the clinic, the diagnosis may be made after careful elimination of other possible causes, when the audiogram shows the particular characteristics described above. On the other hand, the diagnosis is relatively simple; if one examines a group of employees in a noisy industry. The high tone loss does not progress after the subject ceases to be exposed. Tinnitus, however, may continue. Deafness may fluctuate with relation to the immediate period of exposure. Considerable recovery takes place within hours after exposure.

It is well to remember that after early childhood our auditory spectrum gradually shrinks from the high frequency end. This natural aging of our



FIG. 2

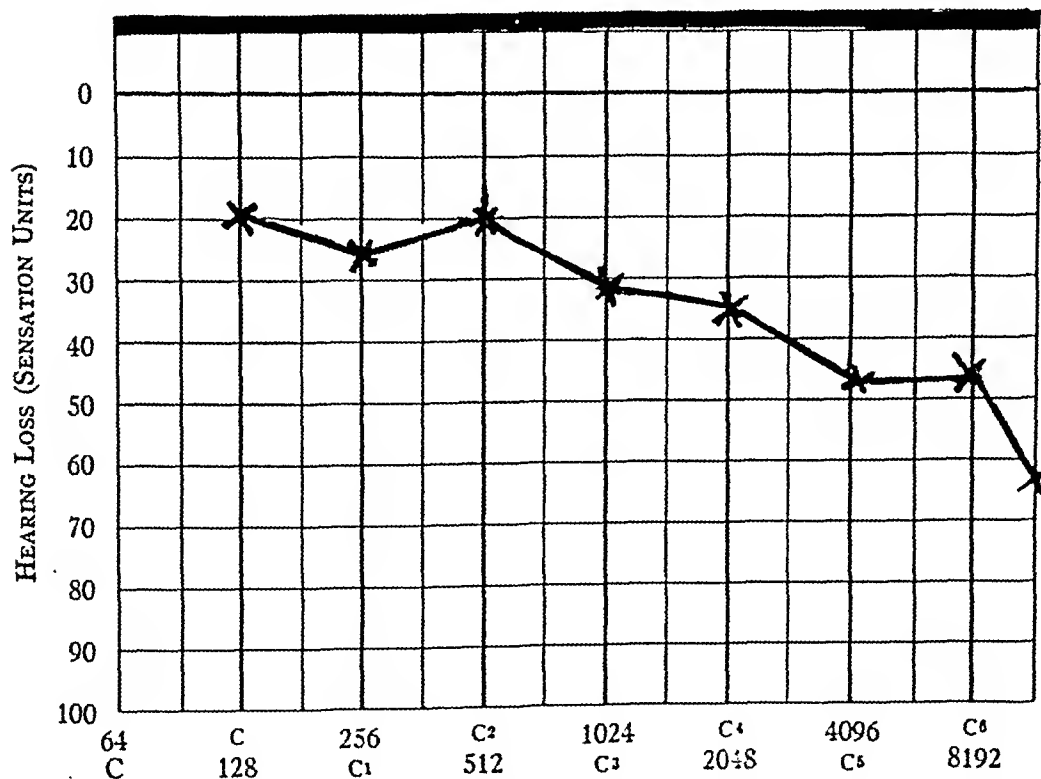
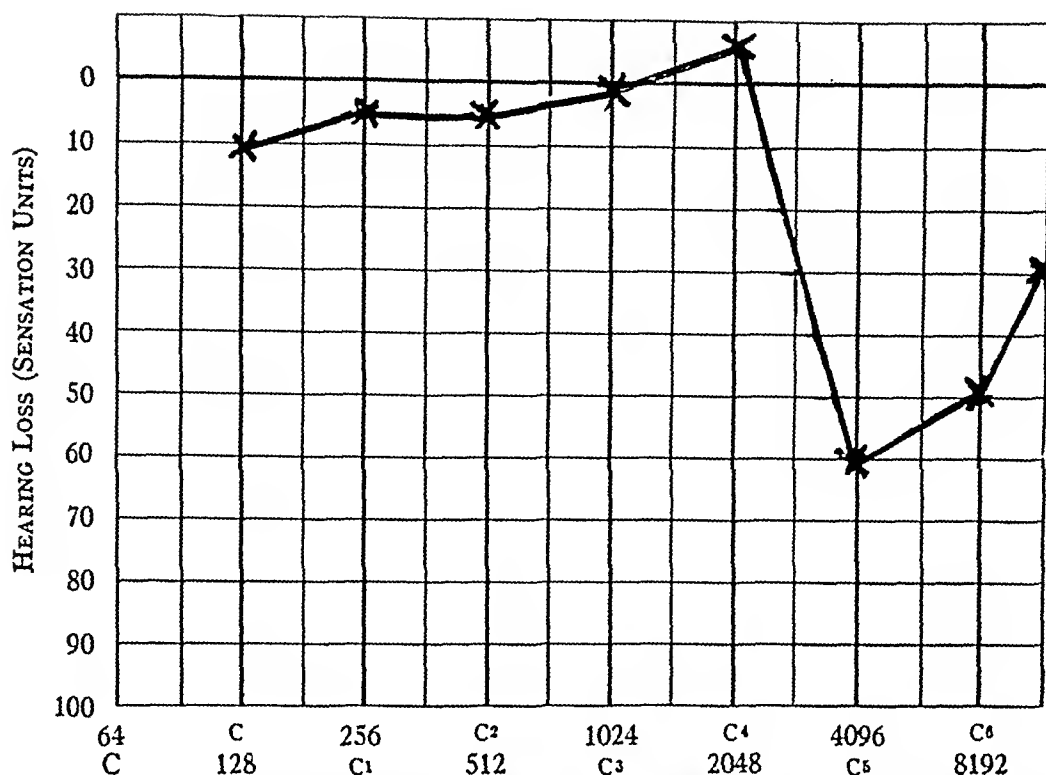


FIG. 3

FIG. 2.—Audiogram typical of early acoustic trauma. Such as may follow exposure for several hours to great sustained noise (i.e. aircraft engine) or exposure to a single explosive noise.

Hearing for the conversational voice may not be affected.

FIG. 3.—Audiogram typical of advanced acoustic trauma. Such as may follow working as a riveter for ten years.

Hearing for the conversational voice would be noticeably affected.

auditory sense organs must be taken into account in the interpretation of our tests. The first evidence of trauma usually appears as a sharply localized dip in the threshold curve between 4,000 and 6,000 cycles per second (Fig. 2). At this time the subject may experience no difficulty in hearing. As trauma continues, hearing for the still higher frequencies is affected, but again very little noticeable effect will occur to the subject. Then the hearing for sounds

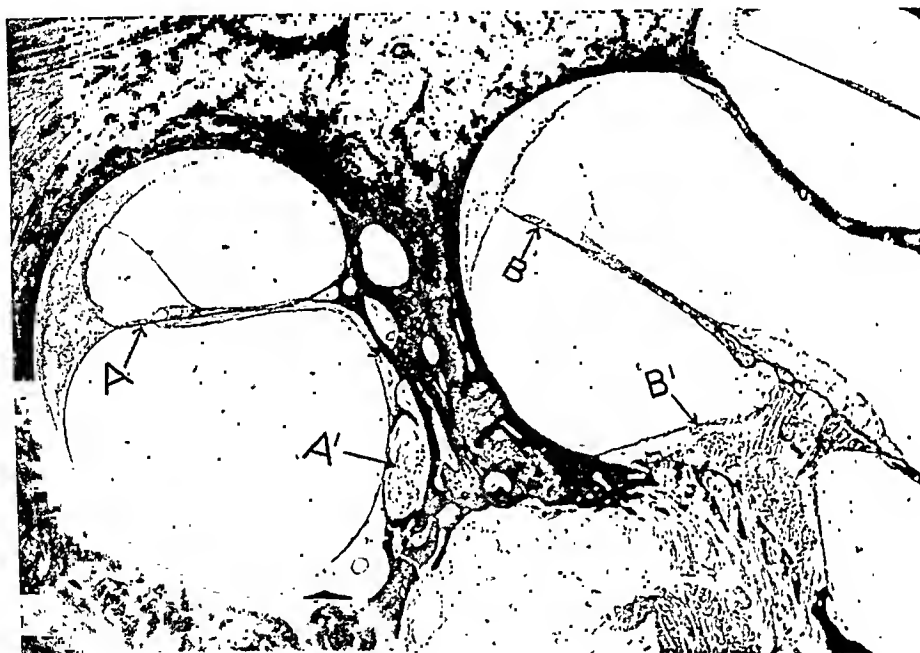


FIG. 4.—Photomicrograph ( $\times 32$ ) of the human cochlea illustrating the pathology of the end-organ in acoustic trauma.  
A. Degeneration of the organ of Corti in the basal coil with associated degeneration of the spiral ganglion cells A'.  
The organ of Corti in the middle coil is more normal (B) and the ganglion cells in the spiral ganglion B' more numerous and healthier.

below 4,000 cycles per second becomes affected, and with this loss difficulty in understanding some speech sounds (consonants and whispered voice) are noted (Fig. 3). The pathologic findings, within the limitations of the method of microscopic examination of the end-organ, are clearly defined changes in the cochlea. They include degeneration of the outer hair cells of the organ of Corti and throwing off of the cells below the basilar membrane. Degeneration of the inner hair cells and secondarily of the spiral ganglion occur with greater trauma (Fig. 4).

Analysis of a large number of cases of acoustic trauma examined in the light of our present knowledge of acoustics and audition indicates a great number of factors influencing the degree of deafness that is seen in acoustic trauma. Some of these factors are:

1. Total time of exposure.
2. Length of exposure in each period.
3. Loudness of the noise.
4. Distance from the source.

5. Age of the subject.
6. Individual differences in susceptibility to acoustic trauma.
7. Duration of the major sound waves.
8. The character of the surroundings in which the noise is produced.
9. The position of each ear with respect to the sound source.
10. The use of protective devices.
11. Previous ear disease.
12. Frequency pattern of the noise.

One of the investigations carried on in this laboratory concerned this last factor, *i.e.*, The relation of the frequency of the traumatizing sound to the degree and type of the resultant deafness.<sup>5</sup> This investigation showed that for equal intensities, low frequency sounds are much less traumatizing than high frequency sounds. Furthermore, the greatest hearing loss was found to be an octave above the frequency of the traumatizing sound. A sharp dip in the threshold around 4,000 cycles per second typical of early acoustic trauma, could be produced only by exposing a subject to a sound of 2,000 cycles per second. It is important to know that exposure to very loud low frequency sounds does not injure the hearing while similar exposure to higher frequency sounds is definitely harmful. With our present knowledge of the ear, one cannot explain the greatest depression occurring an octave above the traumatizing sound. Furthermore, we cannot explain why the 4,096 dip in the audiogram appears in almost every clinical case of early acoustic trauma, regardless of the type of traumatizing noise.

With the development of the science of acoustics, much is being done to protect us from harmful noise. In general, these efforts are directed along three different phases: 1. Elimination of noise at its source. 2. Reducing noise by altering the surroundings. 3. Protection to the ear itself by various obturators, *etc.* Cooperation of the industrial engineer, acoustic physicist and otologist will help to minimize this undesirable by-product of modern civilization.

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# RESECTION OF THE LEFT LOBE OF THE LIVER IN A PATIENT WITH FOUR SEPARATE CARCINOMAS

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WITHIN RECENT YEARS surgeons have extended the operability of cancer, not only within the original site of involvement, but also in the regional and distant metastases. Although many surgeons have resected parts of the liver for various reasons, the subject of the resection of the left lobe of the liver has not been adequately described in the literature. O. H. Wangenstein<sup>1</sup> describes the surgical problems of gastric cancer, with special reference to close coincidental hepatic resection. Other than this, the present surgical literature appears to be scanty. J. Gautier<sup>2</sup> resected the quadrate lobe of the liver for a primary carcinoma, and Benson and Penberthy<sup>3</sup> reported on a surgical excision of a primary tumor of the liver in an infant seven months old, with survival.

The purpose of this paper is to present my experience with the resection of the left lobe of the liver in a man who had four separate and distinct carcinomas. Inasmuch, as the indications for the resection of the left lobe of the liver is so well illustrated in this case, I feel it would serve this paper best if I presented the case history first.

**Case Report.**—The patient, a white male, age 47, was first seen in September, 1939. At this time he complained of gradual and progressive loss of weight over a period of four months, abdominal distress and pain in the right lower quadrant. The physical examination revealed a tender mass in the right lower quadrant, which was firm and freely movable. The roentgenologic examination revealed an obstructive lesion at the cecum. The patient was operated upon in September, 1939, and a large carcinoma of the cecum was found at celiotomy. Approximately 30 cm. of the terminal ileum, the cecum, the ascending colon, the hepatic flexure and a part of the transverse colon with a corresponding V-shaped segment of the mesocolon were resected. An ileotransverse colon-colostomy was then performed.

The patient made an uneventful recovery and left the hospital two weeks after the operation. In September, 1941, a roentgenogram of the large bowel revealed a normal functioning bowel, without evidence of malignant neoplasm (Fig. 1). At this time he had no abdominal complaints. The patient continued to enjoy good health until December, 1944, when he returned to the hospital, complaining of a rather rapidly growing tumor in the region of the right cheek, just over the zygoma. This, he stated, had been present for about two months. The clinical impression was squamous cell carcinoma of the face. This mass was excised by a rather large elliptical resection, and postoperative roentgenotherapy was administered. The microscopic diagnosis was a squamous cell carcinoma.

During the course of this interview it was noted that the patient had lost about 15 pounds in weight, and that he complained of vague abdominal distress, marked by flatulence, distention and cramp-like pain. This was associated with an occasional bloody stool. The physical examination was negative. Roentgenograms of the large bowel

revealed a complete obstruction to the retrograde flow of barium a few centimeters below the splenic flexure. The diagnosis of carcinoma of the splenic flexure (Fig. 2) was made, and the patient was again operated upon.

The abdomen was opened through a large transverse incision. A few centimeters below the splenic flexure a tumor-mass, measuring about ten centimeters in diameter, was encountered. No lymphatic metastases were felt in the omentum or the mesocolon. However, in the region of the left lobe of the liver, high in its dome, there was a small, firm umbilicated mass which one could feel within the substance of the liver.



FIG. 1.—Barium enema two years after resection of carcinoma of cecum.

It was situated in a position where a biopsy would have been most difficult. My impression was that this was a solitary metastases to the left lobe of the liver. Almost the entire transverse colon, the splenic flexure, and a generous share of the descending colon were resected (Figs. 3 and 4). The previous ileocolostomy was found in a good condition, and the small segment of the transverse colon in this area was left behind to afford a good end-to-side anastomosis between it and the sigmoid colon. It was also thought that sparing a segment of the transverse colon would afford better reabsorption of minerals and fluids.

The patient again made an uneventful recovery. He left the hospital in two weeks and returned a week later for the resection of the left lobe of the liver. This procedure will be described separately. About four months after the partial resection of the liver, the patient returned with a small nodule in the skin on the posterior aspect of his neck. This was found to be a squamous cell carcinoma, his fourth separate cancer.

The operation of left hemihepatectomy was performed as follows: It was noted at the previous operation that a transverse incision would not afford the optimal exposure for the left lobe. Therefore, a high midline incision was made extending from the xyphoid down, and slightly to the left of the umbilicus. It was thought that if adequate exposure could not be obtained by this incision, that the incision could be extended transversely. This, however, was not necessary. Upon opening the abdomen the nodule in the left lobe of the liver, previously described, was again noted.

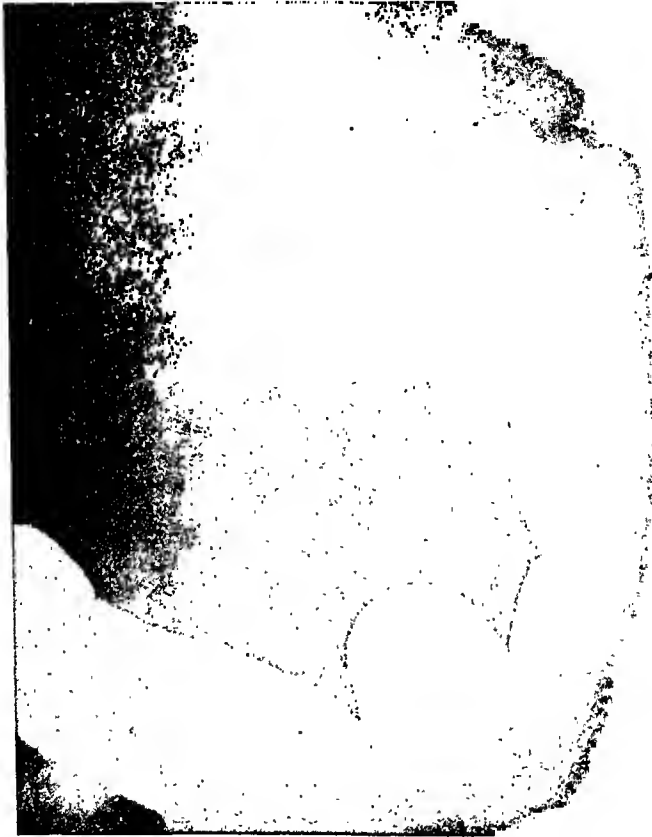


FIG. 2.—Roentgenogram of colon showing carcinoma of splenic flexure.

The coronary ligament of the liver on the left side was divided as well as the ligamentum teres. This latter was used as a handle and greatly facilitated the mobilization of the liver. The cutting of the coronary ligament alone gave an excellent mobilization of the liver. A row of interrupted chromic No. 1 catgut was then placed at about one centimeter from the groove dividing the right and left lobes of the liver. Following this, another row of interrupted catgut sutures were placed in an interlocking fashion. The liver to the left of the two rows of suture was then resected, using scissors. It was possible to feel greater resistance with the scissors at certain points, and when this increased resistance was felt, an additional hemostat was placed before further progress was made in cutting the liver off. Only one large arterial bleeder was encountered, and this was readily caught with an ordinary hemostat. A perfect hemostasis was accomplished after three separate bleeders were ligated over hemostats. A slight sero-sanguineous fluid continued to discharge from the cut-surface of the liver. Part of the ligamentum teres, the triangular ligament, and a part of the coronary ligament, as well

as the neighboring fat and the omentum, were utilized to cover the raw surface of the liver. Five grams of crystalline sulfanilamide and a cigarette drain were inserted into the operating field, and the wound was closed in the usual fashion. The patient made an uneventful recovery except for a moderate discharge of clear, serous, bile-stained fluid



FIG. 3.—Part of the gross specimen of the carcinoma of splenic flexure.

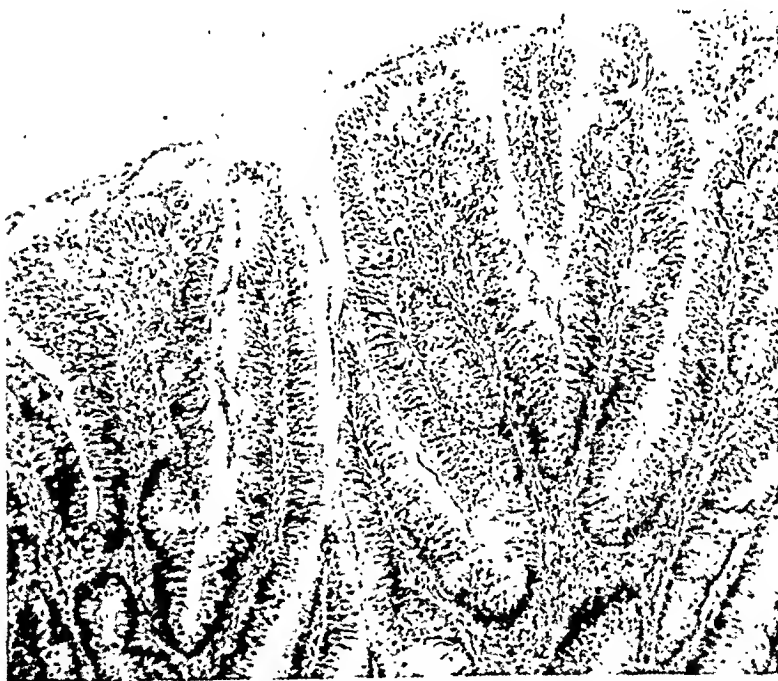


FIG. 4.—Photomicrograph of the carcinoma of the splenic flexure.

from the drainage tract. This continued in diminishing amounts for about three weeks. Three days after his operation his urine was negative; leukocyte count 14,000; icterus index 6; nonprotein nitrogen 30. The patient was discharged from the hospital 12 days after the operation. He continued to improve in a normal convalescent fashion.

Three months after the operation he was back at work, had gained 15 pounds in weight, and was apparently enjoying good health. He returned four months after this operation with a nodule, a squamous cell carcinoma of the posterior aspect of the neck previously described. The resected specimen of the liver weighed 240 Gm. (Fig. 5). The nodule, which we considered to be a solitary metastasis, was found to be, on microscopic examination, an area showing marked focal proliferation of bile ducts with cholangiectasis and focal hepatitis.

In conclusion, a case has been presented in which four separate and different carcinomas have been found and removed. Incident to the resection of the splenic flexure a nodule was found in the left lobe of the liver which, after resection of this lobe, proved to be a focal area of hepatitis.



FIG. 5.—Segments of liver removed (after fixation). The specimens on the left show areas of focal hepatitis.

The indications for the resection of the left lobe of the liver are clearly indicated in this case, if one disregards the final microscopic diagnosis of the liver nodule resected with the lobe. This was peculiar in this particular case because preliminary biopsy of the liver nodule was technically impossible. This nodule had to be considered carcinomatous because of the location of the original tumor in the left half of the colon, and because on palpation it felt like an ordinary metastatic nodule. I felt that, inasmuch as there were no palpable intervening lymphatic metastases, and no other palpable nodules in the right lobe of the liver that the removal of a solitary metastatic nodule



in the left lobe of the liver would afford the patient a chance for a longer survival. Certainly, this same thought is carried out in the operation of radical mastectomy where the original tumor, the breast, the underlying muscles, and the axillary content are removed *en bloc*.

This singular experience indicates that it is possible to resect the left lobe of the liver, with an adequate exposure and good hemostasis. In so doing, one may further extend the operability of cancer in certain well-indicated instances.

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# THE ETIOLOGY AND TREATMENT OF POLYCYTHEMIA RUBRA VERA\*

OBSERVATIONS BASED UPON STUDIES OF BODY FLUID CHANGES IN DOGS SUB-  
JECTED TO PROPRIOCEPTOR DEPRESSOR NEUROTOMY AND EXTENSIVE  
SYMPATHECTOMY, INCLUDING THE CASE REPORT OF A MAN WITH  
POLYCYTHEMIA RUBRA VERA TREATED BY EXTENSIVE PARA-  
VERTEBRAL SYMPATHECTOMY

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POLYCYTHEMIA is a term frequently used to denote an elevation of the red blood cell count without regard for the size of the cells or their hemoglobin content and with no consideration of the total red cell mass. The various classifications of this state, which have been proposed, are based chiefly on the relation of the red cell mass to the plasma volume and total blood volume. "Relative polycythemia" may be said to occur when the red cell count is elevated because of loss of plasma from the blood, *i.e.*, as in burns, however, hemoconcentration is a more common designation. In this condition, the red cell mass remains normal, or less than normal, and the plasma volume and total blood volume are decreased. "Absolute polycythemia" indicates an actual increase in the red cell mass either with or without an increase in total blood volume. The absolute polycythemias are usually considered to be of two types: First, "erythrocytosis" or "secondary polycythemia" in which, in response to known etiologic factors, the red cell mass is increased, usually without marked increase in total blood volume; and, second, "erythremia" or "polycythemia rubra vera," a disease of as yet uncertain etiology characterized by a marked increase in total blood volume due almost entirely to increase in red cell mass, the plasma volume usually being within normal limits.

In all types of secondary polycythemia, that is, absolute polycythemia due to the action of known stimuli, there is a similarity in that all of these conditions present a defect in oxygenation of the systemic arterial blood. The exact means by which this deficient oxygenation of the blood stimulates the production of increased numbers of red blood cells by the bone marrow is not known, however, the fact remains that in conditions characterized by decreased oxygenation of the systemic arterial blood, whether it be due to a shunting of venous blood of low oxygen tension through the patent foramen ovale of congenital heart disease or to inhibition of the respiratory function of immature red cells as occurs after the administration of cobalt,<sup>1</sup> the bone marrow responds by the production of more red cells. Thus, we see increase in the red cell mass in the following conditions: congenital heart disease with defective auricular or ventricular septi, patent foramen ovale or patent ductus arteriosus, some cases of mitral stenosis, pulmonary fibrosis

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\* This work was done on grants from the Douglas Smith Foundation and from Mr. Joseph O. Hanson.

and emphysema, sclerosis of the pulmonary artery (Ayerza's disease), residence at high altitudes, and following poisoning by many chemicals, the action of all of which has not been as thoroughly studied as has that of cobalt. One of the most severe cases of secondary polycythemia we have seen was that of a man 24 years of age, who was found to have a cavernous hemangioma of the left lung with a functioning arteriovenous shunt. This case has been reported in detail elsewhere.<sup>2</sup>

Vaquez reported the first case of polycythemia rubra vera, or erythremia, in 1892,<sup>3</sup> with further observations in 1895.<sup>4</sup> During the next few years numerous cases were recorded in the literature, Osler's papers in 1903 and 1904 arousing considerable interest.<sup>5</sup> Turk,<sup>6</sup> 1900 and 1904, first pointed out the leukocytosis seen so commonly in association with erythremia and also emphasized the peripheral blood picture evidence for hyperplasia of both the leukopoietic and erythropoietic elements of the myeloid tissue.<sup>7, 8</sup> As a result of these original observations plus numerous case reports made in the first decade of this century, erythremia became recognized as a disease entity characterized by increase in the red cell mass and total blood volume with frequent evidence of general hyperactivity of the marrow elements. The disease is somewhat intermittent in character but is slowly progressive, with eventual fatality, due usually to thrombosis of major or vital vessels. The half century that has passed since its original description has seen the contribution of descriptive literature and some improvements have been made in the therapy of the condition, but few important observations have been made either on the nature of the condition or on its etiology. Thus, as has been indicated, polycythemia rubra vera became recognized as a disease entity, but little is known of its etiology.

Our interest in the subject of polycythemia was aroused by observations made on dogs which were being studied for what, at that time, was thought by us to be a completely unrelated condition—hypertension. The basis for our experiment was as follows: The carotid sinus and cardio-aortic proprioceptive nerves constitute the afferent limbs of a reflex arc that is of fundamental importance in regulation of the blood pressure. Impulses are known to pass centripedally through these nerves to the vasomotor centers of the brain stem from which areas efferent impulses course outward to the heart and blood vessels of the body by way of the sympathetic nerves and the vagus. This reflex mechanism exerts its control of the circulation in part, by alteration of cardiac function but its major influence is brought about through variation of peripheral vascular tone. Thus, by experimental tampering with the afferent proprioceptive and the efferent vagal and sympathetic nerves, one is able to induce various acute and chronic changes in peripheral vasomotor tone. This, at once, opens up a broad field for investigative work, much of which has been done, as is evidenced by many brilliant reports since Claude Bernard's original description of vasoconstrictor fibers in 1852.<sup>9</sup> However, most of this work has concerned acute effects related to alteration of the caliber of peripheral vessels and much of it has dealt solely with

changes in blood pressure. We were intrigued by the prospect of observing animals maintained in states of chronic peripheral vasoconstriction and vasodilation, and our first interest was not so much with the effect of this chronic alteration of vasomotor tone on blood pressure as it was to record changes in certain of the body fluids. This report is in part based on those observations.

The cardio-aortic depressor nerve was first described by Cyon and Ludwig, in 1866.<sup>10</sup> It is composed of purely afferent fibers which are depressor in function. These fibers terminate at various points in the wall of the aorta and heart and are generally considered to be vagal in origin since in most animals they are indistinguishably bound within the sheath of the vagus nerve and pass to the medullary centers together with other fibers of the vagus. In the rabbit, these cardio-aortic depressor fibers are collected into a separate nerve that joins the vagus high in the cervical region. In 25 per cent of dogs they form a separate nerve lying in the vagosympathetic trunk between the vagus laterally and the sympathetics medially. In most dogs, however, the fibers are not grossly identifiable. The carotid sinus is a slight enlargement in the region of the bifurcation of the common carotid artery, although in many cases it solely involves the commencement of the internal carotid. The carotid sinus nerve is a branch of the glossopharyngeal which terminates in the wall of the carotid sinus. It, like the cardio-aortic nerve, is purely afferent and depressor in function.

Both of these proprioceptive nerves bear end-organs situated in the walls of the vessels supplied. These end-organs are of two types: presso-receptor and chemoreceptor, the former being by far the more significant. The presso-receptors discharge impulses when they are mechanically stimulated by stretching of the vessel wall as it is subjected to increased pressure. The chemoreceptors are stimulated by oxygen lack or carbon dioxide excess. By oscillographic methods both the carotid sinus and cardio-aortic nerves have been shown to discharge impulses centrally at varying rates, the rate increasing with elevation of blood pressure and decreasing with fall of blood pressure. During the cardiac cycle, for example, the greatest frequency of discharge occurs during systole and the least during diastole.<sup>11</sup> Thus, these nerves continuously bombard the medullary centers with depressor impulses of such frequency as to maintain a constant normal blood pressure. From the medullary centers cardio-accelerator, cardio-inhibitory, vasoconstrictor and vasodilator impulses pass to the periphery by way of various sympathetic and vagal pathways. In 1923, Hering<sup>12</sup> first showed that acute hypertension could be produced in rabbits by section of both the carotid sinus and cardio-aortic depressor nerves. His efforts to produce chronic hypertension did not meet with as much success. In 1931, Heymans<sup>13</sup> reported the successful production of chronic hypertension in dogs by a similar operation. To Hering and to Heymans, their coworkers and students, should go much of the credit for the present day understanding of the physiology of these regulator nerves.

## METHODS

As we approached our problem we knew from the experience of ourselves and others that a chronic vasoconstriction could be produced by ablation of the afferent depressor pathways which have just been described.<sup>14</sup> It was planned to produce chronic vasodilatation by extensive sympathectomy. Healthy adult dogs were used exclusively. To produce chronic peripheral vasoconstriction we used our modification of the original Heymans-Hering operation.<sup>15</sup> With aseptic technic, under light ether anesthesia, the neck was opened in the midline and the right vagosympathetic trunk and right carotid bifurcation visualized. First, the sheath of the vagosympathetic trunk was incised and an attempt made to identify the right cardio-aortic depressor nerve. As has been mentioned, in 25 per cent of the animals the nerve could be identified as a slender filament lying between the vagus laterally and the sympathetic trunk medially. If the nerve could be identified, it, together with the sympathetic fibers were sectioned and a segment excised. However, in most instances, accurate recognition was not possible, so an alternate method was used. This consisted of isolation of a rather constant, dense, white core of fibers in the centrolateral part of the vagus trunk. In many postmortem dissections we had determined that the fibers composing this core were distributed to areas below the level of the heart and, thus, could not contain afferent cardiac fibers. This isolated core of vagal fibers was preserved and the remainder of the vagosympathetic trunk together with its sheath divided and a segment excised. The carotid bifurcation was then visualized and ligatures tied about the internal, external and common carotid arteries approximately two centimeters in each direction from the bifurcation. The abundant fibers of the carotid sinus nerve were included in one of the superior ligatures. The entire carotid bifurcation was then excised within the area limited by the ligatures. The same procedure was then carried out on the left side except that on this side the entire vagosympathetic trunk was divided and a segment excised. The pertinent effect of this operation is interruption of all of the cervical afferent depressor pathways. With the loss of incoming depressor impulses the medullary centers are without inhibition. Thus, they send out a preponderance of cardio-accelerator and vasoconstrictor impulses resulting in an increase in heart rate and a marked peripheral vasoconstriction. Hypertension is the obvious result. We do not wish to make a detailed description of the blood pressure changes that occur in these animals except to indicate that this vasoconstriction can be easily demonstrated by increased resistance to perfusion of the distal end of a severed major peripheral artery and to point out that in our experience the hypertension is maintained, usually at a high level, for as long as we have observed our animals (several animals have been under observation for more than four years).<sup>15</sup>

Chronic peripheral vasodilatation was brought about by three-stage or two-stage radical paravertebral sympathectomy, ganglionectomy and splanchnic

nicectomy. The first operation consisted of the transpleural resection of the left stellate ganglion, the entire sympathetic trunk including the sympathetic ganglia and the rami communicantes from the first thoracic to the first or second lumbar levels inclusively, together with all of the left splanchnic nerves and a considerable portion of the celiac ganglion. At the second operation, the right paravertebral region was approached transpleurally and a similar resection carried out. Both of these operations were performed under positive pressure intratracheal ether anesthesia with the animal in apnea. Since the second lumbar ganglia and their rami communicantes are apt not to be easily identified in all animals, in some of them it was necessary to do a third operation which consisted of the transabdominal resection of the remaining portions of the abdominal sympathetic trunk. As a result of these operations all of the efferent cardio-accelerator and vasoconstrictor pathways were interrupted and a loss of peripheral vasomotor tone occurred. This is manifest by hypotension. Due to some regeneration of nerve fibers and some local neuromuscular adjustments there is a tendency for these animals to recover some peripheral vascular tone but recovery is rarely complete and develops only slowly.

Our original aim was to study dogs prepared by the above methods from the standpoint of alteration in plasma volume, red cell mass, total blood volume, intra- and extracellular fluid and total body water with the animals maintained on standard kennel rations under constant laboratory conditions. Plasma volume was determined using our modification of the Gibson and Evans T-1824 dilution method, the blue dye concentration being determined in serum samples by the use of the Evelyn photo-electric microcolorimeter.<sup>16</sup> We had used this method extensively on both man and dogs and felt that under the conditions of our experiment a satisfactory degree of accuracy could be obtained. Red cell mass and total blood volume were calculated from the dye-determined plasma volume and the hematocrit. Reliable hematocrit readings were obtained using the Van Allen capillary tube without dilution and with centrifugation at 3,000 rpm. for 30 minutes. The volume of the extracellular fluid was approximated from dilution curves of sodium thiocyanate, using the method described by Crandall and Anderson.<sup>17</sup> Total body water was measured by means of sulfanilamide dilution curves and total blood water as described by Painter.<sup>18</sup> Both thiocyanate and sulfanilamide concentrations were read colorimetrically in the Evelyn photo-electric macrocolorimeter. Record was also made of the blood pressure, pulse rate, red blood cell count and the hemoglobin level. Twenty-nine normal mongrel dogs were used in the experiment. Ten of the dogs constituted a control group, and either were not subjected to surgery or died too soon after operation to warrant any conclusions as to the effect of the operation. Thirteen animals were made hypertensive and six were subjected to sympathectomy. All of the animals were observed for a sufficient length of time before and after operation to be certain of the validity of our results (Charts 2 and 3).

## CONTROL OBSERVATIONS ON BODY FLUIDS

Observations made on all 29 of the dogs during the control period are summarized in Table I. Each figure in this chart represents the average of many determinations made during a one- to 16-month preoperative period in those dogs which were subsequently subjected to surgery and, in the case of several of the dogs which were retained as controls without surgery, the

TABLE I

Control and preoperative observations on 29 normal dogs. Each figure in this table represents an average of all designated readings made on each animal during a one to 16 months' period. Blood pressures are recorded in millimeters of mercury as mean arterial pressures obtained by needle puncture of the femoral artery.

DOG NO.	PLASMA VOLUME		RED CELL MASS		TOTAL BLOOD VOLUME		"AVAILABLE" FLUID		TOTAL BODY WATER		HEMATOCRIT	BL.PR.
	Total	cc/kgm.	Total	cc/kgm.	Total	cc/kgm.	Total	cc/kgm.	Total	cc/kgm.		
459	805	56	645	45	1445	101	4158	291	8370	589	44	136
597	622	54	690	58	1312	112	3485	325	6923	645	48	170
629	664	49	769	55	1433	104	3520	264	7723	579	53	159
453	606	51	642	54	1248	105	3495	293	7060	594	51	142
310	626	52	494	44	1120	96	2572	229	7388	651	44	145
400	478	58	388	46	866	104	2448	299	5810	704	45	147
330	340	49	256	36	596	85	2076	285	4528	652	43	131
305	632	54	545	47	1177	101	2943	245	6812	592	46	132
557	627	53	540	46	1167	99	3212	272	7226	608	46	143
111	1046	43	909	37	1955	80					46	140
598	592	52	600	51	1192	103	3085	268	7094	625	48	143
309	445	49	372	40	817	89	2088	226	5296	581	45	138
303	596	58	502	49	1098	107	2945	282	7039	690	49	138
307	751	53	799	54	1550	107	3726	257	8652	594	51	132
596	810	55	737	51	1547	106	4617	307	10643	710	47	150
627	654	55	600	52	1254	107	3665	308	7276	607	47	140
460	643	55	585	46	1228	101	3256	255	6864	564	48	148
220	616	57	502	47	1118	104	2910	261	7005	644	45	134
326	676	55	554	46	1230	101	3363	267	8244	676	45	141
394	540	54	490	42	1030	96	2999	284	6780	650	48	133
221	778	57	551	42	1329	99	3632	249	7927	593	42	132
21	604	57	447	40	1051	97	3046	286	6844	640	43	154
306	950	59	749	47	1699	106	4580	250	10760	672	44	124
327	500	56	419	48	919	104	2266	249	6281	713	45	130
624	730	52	777	54	1507	106	4160	292	9610	669	51	148
393	687	64	479	45	1166	109	3468	324	7594	705	41	136
277	780	58	602	45	1382	103	3784	274	8576	639	44	136
599	745	56	712	54	1457	110	4071	311	8577	659	49	149
625	818	49	785	48	1603	97	4777	350	10163	688	49	163
AVERAGE		54		47		101		279		640	46	142

figures represent many readings made during the course of one and one-half years of observation. Dog No. 394 is typical of the latter group. As may be seen from examination of Table I and Figures 1 and 2, the plasma volume varied from 43 to 64 cc. Kg. body weight, averaging 54 cc. Kg. of body

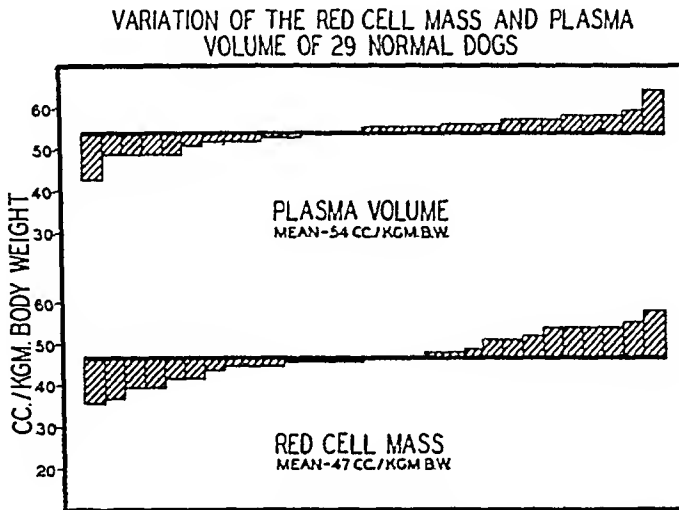


FIG. 1.—Variation of the red cell mass and plasma volume of 29 normal dogs expressed in cubic centimeters per kilogram of body weight. The solid horizontal lines represent the arithmetic means obtained for the entire group.

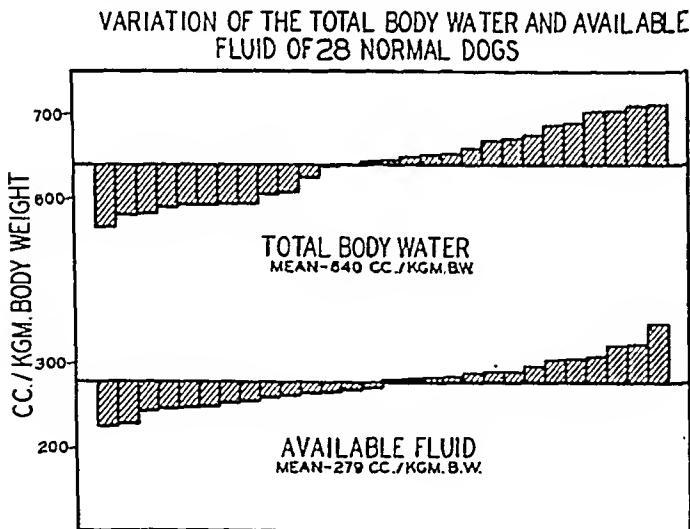


FIG. 2.—Variation of the "available fluid" and total body water of 28 normal dogs expressed in cubic centimeters per kilogram of body weight. The solid horizontal lines represent the arithmetic means obtained for the entire group.

weight, with most of the readings near the arithmetic mean. The higher values were uniformly encountered in the lean, rangy, short-haired dogs while the lower values were observed in the fat, stocky, long-haired animals. Essentially similar correlations held for the other body fluid levels. The red cell mass varied from 36 to 58 cc. Kg. of body weight, averaging 47 cc. The total blood volume varied from 80 to 112 cc. Kg. of body weight, averaging 101 cc. The "available fluid" varied from 226 to 350 cc. Kg. of body weight,



# POLYCYTHEMIA RUBRA VERA

averaging 279 cc. The total body water varied from 564 to 713 cc. Kg. of body weight, averaging 640 cc. These findings are in agreement with the results of other writers who have used the same or similar methods. Although there was a fairly wide variation in these values in a group of dogs of varying build, for any given dog there was little fluctuation in the level of any of the body fluids so long as the animal was maintained on the standard kennel routine and did not become ill. This is indicated in the record of Dog No. 394 in Figure 3, which indicates less than a plus or minus 10 per cent deviation in plasma volume, red cell mass and total blood volume during a period of observation extending from February, 1941, to June, 1942. Fluctuations of

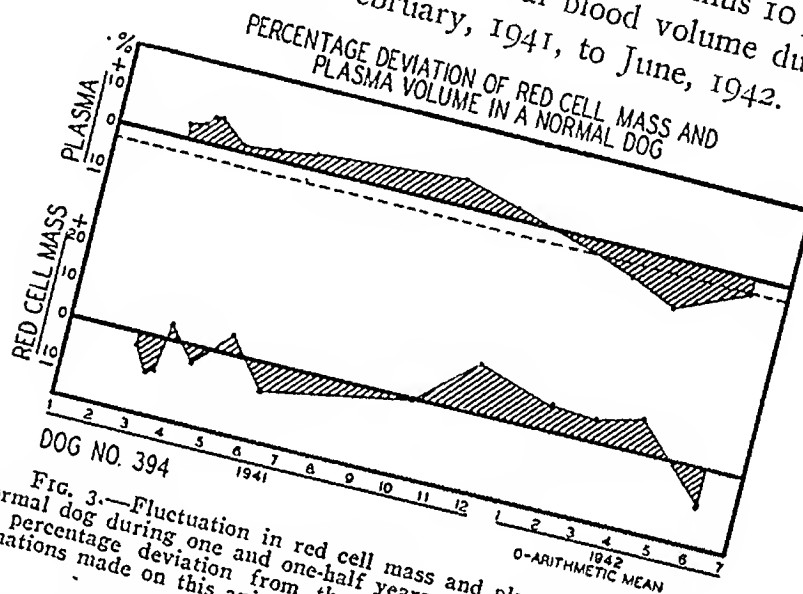


FIG. 3.—Fluctuation in red cell mass and plasma volume of a normal dog during one and one-half years of observation expressed as percentage deviation from the arithmetic mean of all determinations made on this animal.

similar magnitude were also observed in "available fluid" and total body water determinations in this particular animal. In the entire group of dogs: The hematocrit ranged from 42 to 53 per cent, averaging 46 per cent, while the mean arterial blood pressure ranged from 124 to 170 mm. of Hg., averaging 142 mm. of Hg.

## BODY FLUID CHANGES FOLLOWING PROPRICEPTOR DEPRESSION

### NEUROTOMY

Plasma volume, red cell mass, and total blood volume determinations were made on all 13 of the dogs subjected to proprioceptor depressor neurotomy, while "available fluid" and total body water determinations were made on only eight. Evidence for the existence of chronic peripheral vasoconstriction in these dogs is the fact that following operation their average mean arterial blood pressure ranged from 160 to 301 mm. of Hg., averaging 216 mm. of Hg. for the group. Thus, the blood pressure whereas before operation their blood pressures had ranged from 131 to 170 mm. of Hg., averaging 143 mm. Hg. for the group. Each figure increased 51 per cent following proprioceptor depressor neurotomy. Each figure tabulated in Chart 2 and in Figures 4, 5, 6, 7 and 8 represents a level reached after the establishment of chronic peripheral vasoconstriction. From these data it may be seen that ten of the animals had a fall in plasma volume of from

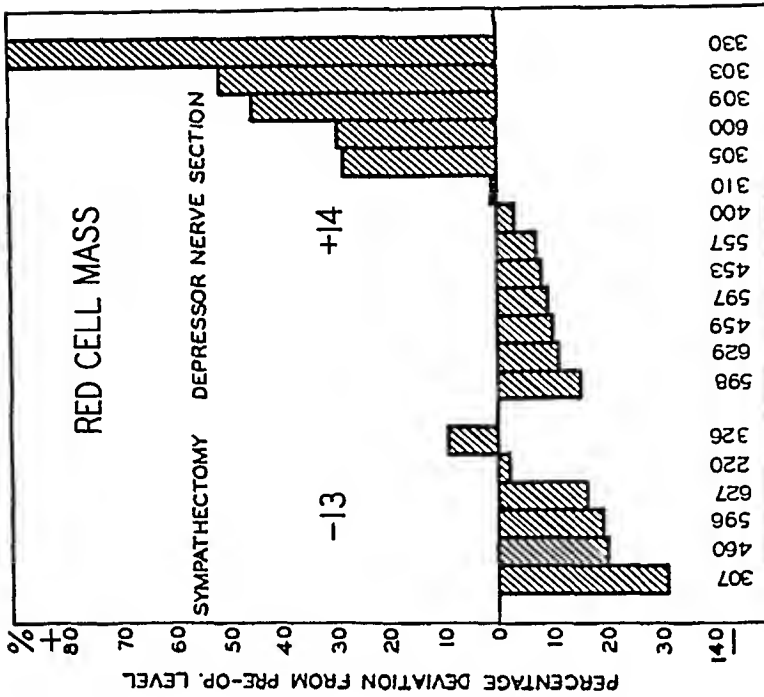


FIG. 5.—Changes in red cell mass observed following proprioceptor depressor neurotomy and extensive paravertebral sympathectomy expressed as percentage deviation from the average pre-operative level (0) for each animal. The dogs are identified by the numbers at the bottom of the chart. The average over all change for each group is indicated by the large numbers above the horizontal line.

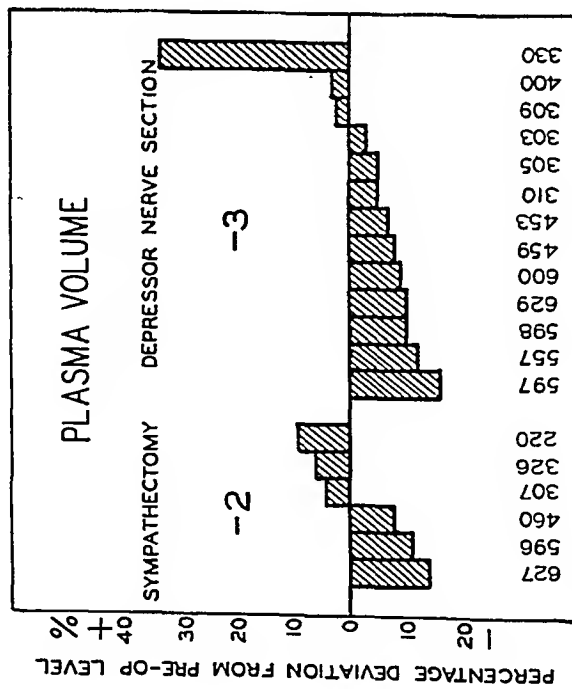


FIG. 4.—Changes in plasma volume observed following proprioceptor depressor neurotomy and extensive paravertebral sympathectomy expressed as percentage deviation from the average pre-operative level (0) for each animal. The dogs are identified by the numbers at the bottom of the chart. The average over all change for each group is indicated by the large numbers above the horizontal line.

3 per cent to 16 per cent, and three animals an increase of 2 per cent, 3 per cent and 35 per cent, respectively, for an average over-all decrease in plasma volume of 3 per cent. Seven of the animals had a decrease in red cell mass of from 3 per cent to 15 per cent, and six animals an increase of from 1 per cent to 92 per cent, for an average over-all increase in red cell mass of 14 per cent. Eight of the animals had a decrease in total blood volume of from 2 per cent to 15 per cent, and five animals an increase of from 6 per cent to 59 per cent, for an average over-all increase in total blood volume of 4 per cent. Three of the animals had a decrease in "available fluid" of 1 per cent, 4 per cent and 6 per cent, respectively, and five animals an increase of from 1 per cent to 27 per cent, for an average over-all increase in "available fluid" of 8 per cent. Three of the animals had a decrease in total body water of 3 per cent, 7 per cent and 9 per cent, respectively, and five animals an increase of from 1 per cent to 19 per cent, for an average over-all increase in total body water of 2 per cent.

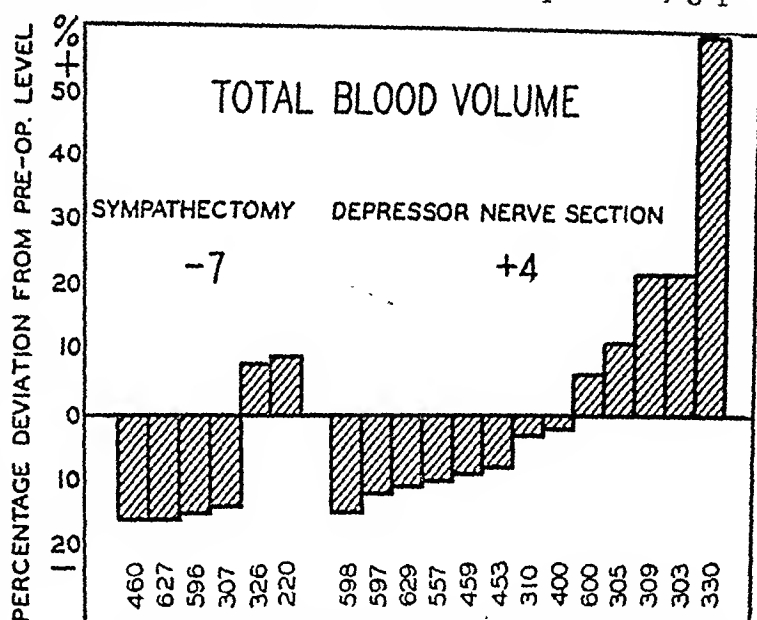


FIG. 6.—Changes in total blood volume observed following proprioceptor depressor neurotomy and extensive paravertebral sympathectomy expressed as percentage deviation from the average preoperative level (0) for each animal. The dogs are identified by the numbers at the bottom of the chart. The average over all change for each group is indicated by the large numbers above the horizontal line.

#### BODY FLUID CHANGES FOLLOWING EXTENSIVE PARAVERTEBRAL SYMPATHECTOMY

Plasma volume, red cell mass, total blood volume, "available fluid," and total body water determinations were made on all six of the dogs subjected to extensive sympathectomy. Following their last stage of sympathectomy the average mean arterial blood pressure of these animals ranged from 107 to 150 mm. of Hg., averaging 128 mm. of Hg. for the group, whereas, before operation their blood pressures had ranged from 132 to 150 mm. of Hg., averaging 141 mm. of Hg. for the group. Thus, the mean arterial blood pressure for this group of six animals decreased 9 per cent following operation. The detailed pressure changes for each animal are found in Table 3. This chart also indicates the changes observed in the various body fluids following sympathectomy. The mode of presentation is the same as described for Table 2. It may be seen that three of the animals had a decrease in plasma volume of 8 per cent, 11 per cent and 14 per cent, respectively, and three animals an increase of 4 per cent, 6 per cent and 9 per cent, respectively, for an average over-all decrease in plasma volume of 2 per cent. Five

TABLE II  
for depressor neurotomy on the blood pressure and body fluids of 13 dogs. Each figure in this table represents an average level which was attained by the animal following this operation.

DOG NO.	WEIGHT (kgm.)	DURATION OF OBSERVATION (months)			AVERAGE BLOOD PRESSURE (mm. Hg.)			PLASMA VOLUME (cc.)			RED CELL MASS (cc.)			TOTAL BLOOD VOLUME (cc.)			"AVAILABLE FLUID" (cc.)			TOTAL BODY WATER (cc.)		
		BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN
598	11.6	5	10	145	301	+110	592	550	-10	600	510	-15	1192	1040	-15							
629	15.6	10	8	159	270	+70	664	595	-10	769	895	-11	1435	1280	-11							
459	15.4	2	11	136	206	+51	805	740	-8	645	590	-10	1445	1320	-9							
597	12.7	10	6	170	245	+45	822	520	-16	690	850	-9	1512	1150	-12							
455	13.2	2	18	142	215	+51	606	565	-7	642	585	-8	1248	1160	-8	5495	-4	7060	7200	+2		
557	11.5	2	9	145	212	+48	627	550	-12	540	500	-7	1187	1050	-10	5215	-6	7228	7500	+1		
400	8.9	5	1	147	174	+18	478	495	+5	398	357	-5	866	850	-2	2448	+1	5810	8250	+8		
510	12.5	2	2	145	191	+52	636	590	-5	494	500	+1	1120	1090	-3	2572	+21	7898	6700	-9		
505	10.8	2	4	132	201	+52	652	600	-5	545	700	+28	1177	1800	+11	2945	-1	6912	6600	-3		
600	22.6	2	6	140	160	+14	1046	950	-9	909	1170	+29	1955	2180	+6							
509	11.0	2	*6	138	198	+45	445	460	+2	572	540	+45	917	1000	+22	2088	+27	5286	5600	+6		
505	12.5	1	*6	188	270	+102	596	580	-3	502	760	+51	1098	1540	+22	2945	+16	7059	8550	-7		
550	7.6	1	6	151	164	+25	340	460	+55	256	490	+92	596	950	+59	2076	+15	4528	5400	+19		
AVERAGE					+51		-5				+14		+4				+8					+2

\* See Figs. 9 and 10 for subsequent course.

PIN-Propriocceptor Depressor Neurotomy.

TABLE III  
Effect of extensive paravertebral sympathectomy on the blood pressure and body fluids of six dogs. Each figure in this table represents an average level which was attained by the animal following this operation.

DOG NO.	WEIGHT (kgm.)	DURATION OF OBSERVATION (months)			AVERAGE BLOOD PRESSURE (mm. Hg.)			PLASMA VOLUME (cc.)			RED CELL MASS (cc.)			TOTAL BLOOD VOLUME (cc.)			"AVAILABLE FLUID" (cc.)			TOTAL BODY WATER (cc.)		
		BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN	BEFORE	AFTER	PIN
507	15.7	5	12	132	130	0	751	780	+4	709	550	-51	1550	1350	-14	5726	+15	8652	8600	-1		
460	11.9	2	2	148	128	-15	645	594	-8	595	440	-20	1228	1055	-16	5256	-8	6864	7150	+4		
598	16.5	5	12	160	150	0	810	720	-11	737	600	-19	1847	1520	-25	4617	+5	10645	8550	-20		
627	11.9	4	11	140	155	-5	654	560	-14	600	500	-16	1254	1060	-16	5665	+10	7276	5400	-26		
220	11.5	5	*2	154	107	-20	616	670	+9	502	550	+9	1118	1280	+9	5910	+10	7005	7000	0		
526	12.4	2	*4	141	122	-15	676	720	+6	554	610	+10	1280	1350	+8	5565	+11	8244	7900	-4		
																	+7					-9

of the animals had a decrease in red cell mass of from 2 per cent to 31 per cent, and one animal had an increase of 9 per cent, for an average over-all decrease in red cell mass of 13 per cent. Four of the animals had a decrease in total blood volume of from 14 per cent to 16 per cent, and two animals an increase of 8 per cent and 9 per cent, respectively, for an average over-all decrease in total blood volume of 7 per cent. One of the animals had a decrease of 8 per cent in "available fluid," while five of the animals had an increase of from 3 per cent to 15 per cent, for an average over-all increase of 7 per cent. Four of the animals had a decrease in total body water from 1 per cent to 26 per cent, one animal showed no change, and one animal had an increase of 4 per cent, for an average over-all decrease in total body water of 8 per cent.

In both of the foregoing groups of animals changes in hematocrit and hemoglobin determinations and red blood cell counts were observed to parallel the changes which have already been charted for the red cell mass. Some of these alterations will be shown later in the report.

#### PRELIMINARY CONCLUSIONS AND FURTHER EXPERIMENTATION

After comparison of the above data recorded after establishment of chronic peripheral vasoconstriction and chronic peripheral vasodilatation with the control and preoperative observations, we were of the opinion that significant changes had occurred in neither plasma volume or total body water. We felt that barely significant increases had occurred in the fluid available for the solution of sodium thiocyanate and that this increase was almost identical in both groups of animals. Since the plasma volume in the two groups had shown no alteration this indicated that in states of both vasoconstriction and vasodilatation slight but definite increase had occurred in the volume of the extracellular fluid, the change being of equal proportion in both groups of animals. The most striking alterations were observed in red cell mass and total blood volume. Four of the six animals subjected to sympathectomy showed substantial decrease in red cell mass and total blood volume as great or greater than that observed following proprioceptor depressor neurotomy. Also, six of the 13 animals subjected to proprioceptor depressor neurotomy showed spectacular increases in red cell mass reaching levels far greater than had been observed to occur spontaneously in the preoperative period in any animal or during the entire period of observation of the control

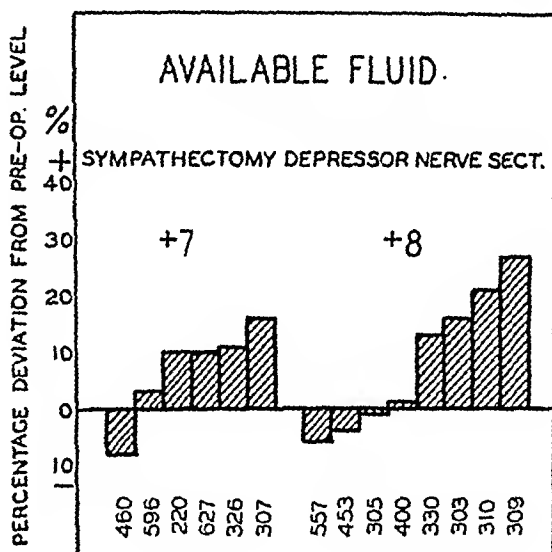


FIG. 7.—Changes in "available fluid" observed following proprioceptor depressor neurotomy and extensive paravertebral sympathectomy expressed as percentage deviation from the average preoperative level (O) for each animal. The dogs are identified by the numbers at the bottom of the chart. The average over all change for each group is indicated by the large numbers above the horizontal line.

animals. We also felt that the average difference in red cell mass between the

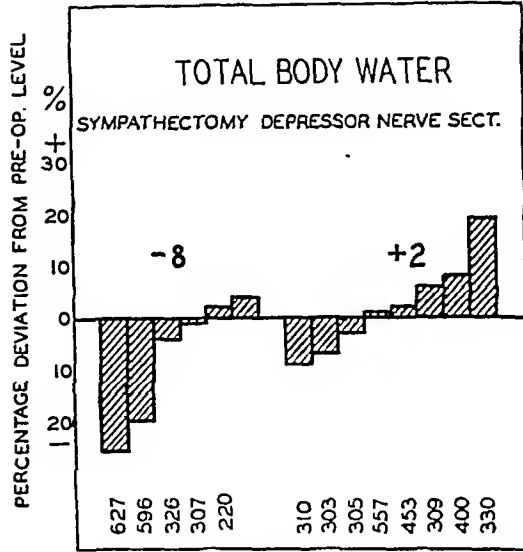


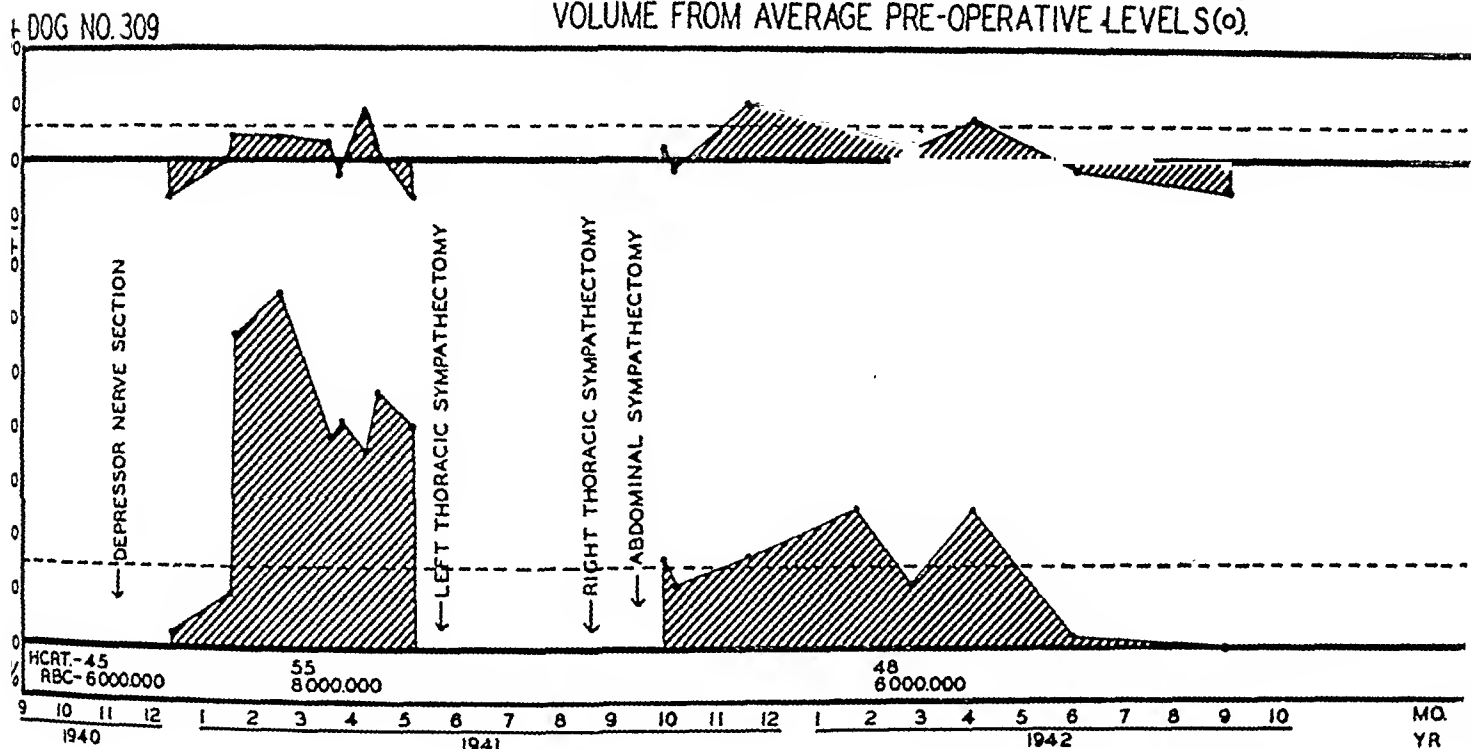
FIG. 8.—Changes in total body water observed following proprioceptor depressor neurotomy and extensive paravertebral sympathectomy expressed as percentage deviation from the average pre-operative level (O) for each animal. The dogs are identified by the numbers at the bottom of the chart. The average over all change for each group is indicated by the large numbers above the horizontal line.

two groups of animals was of significance, the dogs with chronic peripheral vasodilation having an average 11 per cent decrease and the dogs with chronic peripheral vasoconstriction having an average 14 per cent increase in red cell mass.

Since significant absolute changes in red cell mass had occurred in opposite directions in the diametrically opposite states of vasoconstriction and vasodilatation, interest was aroused as to the nature of this relationship which had been observed, and an experiment was devised to further explore this problem. Since we had at our disposal animals with chronic peripheral vasoconstriction and marked polycythemia which had apparently resulted from proprioceptor depressor neurotomy, the next obvious step was to perform

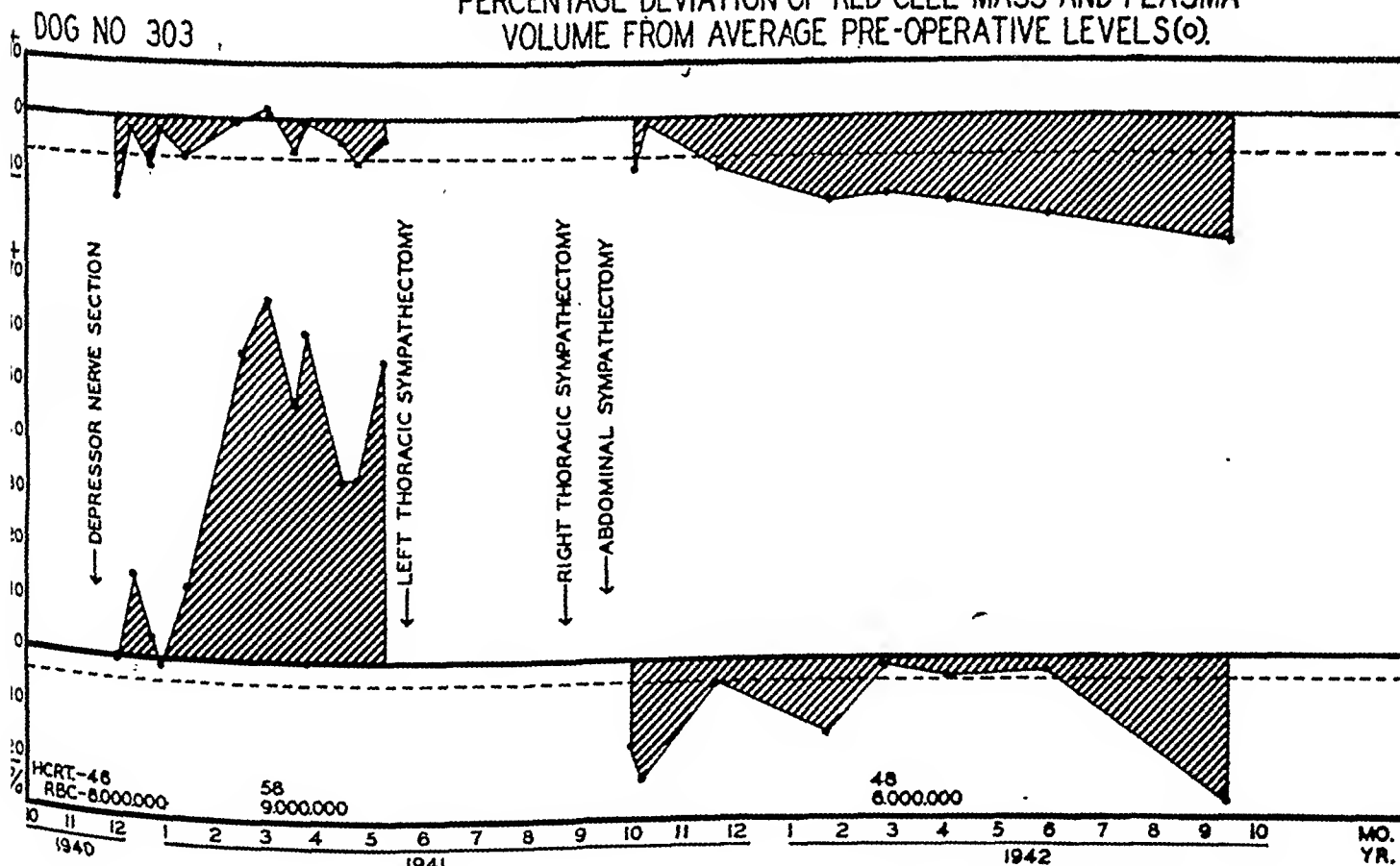
extensive paravertebral sympathectomy upon these animals in an attempt to abolish the chronic peripheral vasoconstriction and then observe the body fluid changes which might occur. Polycythemic animals Nos. 303 and 309 were selected for this experiment, and the results observed are recorded in Table 4 and Figures 9 and 10. Although we had not observed polycythemia in all of the animals subjected to proprioceptor depressor neurotomy, 40 per cent of them had been so affected, and it was felt that some information of value might be obtained by subjecting the already sympathectomized animals to proprioceptor depressor neurotomy and observing the body fluid changes that might occur following this secondary operation. Nonpolycythemic animals Nos. 220 and 326 were selected for this experiment and the results observed are recorded in Table 4 and Figures 11 and 12. No significant alteration in plasma volume, red cell mass, total blood volume, red blood cell count or hematocrit was observed in Dogs Nos. 220 and 326 following proprioceptor depressor neurotomy. That the proprioceptor depressor neurotomy was actually accomplished is indicated by the fact that the mean arterial blood pressure of Dog. No. 220 increased from 107 mm. of Hg. post-sympathectomy to 184 mm. of Hg. following proprioceptor depressor neurotomy, a 30 per cent increase over the dog's normal pressure of 134 mm. of Hg. The blood pressure of Dog. No. 326 increased from 122 mm. of Hg. postsympathectomy to 166 mm. of Hg. following proprioceptor depressor neurotomy, an 18 per cent increase over this dog's normal pressure of 141 mm. of Hg.

PERCENTAGE DEVIATION OF RED CELL MASS AND PLASMA  
VOLUME FROM AVERAGE PRE-OPERATIVE LEVELS(°).



9.—Fluctuations in red cell mass, plasma volume, red blood cell count and hematocrit during a two-year period of observation Dog 309 which was first subjected to proprioceptor depressor neurotomy and later to total paravertebral sympathectomy.

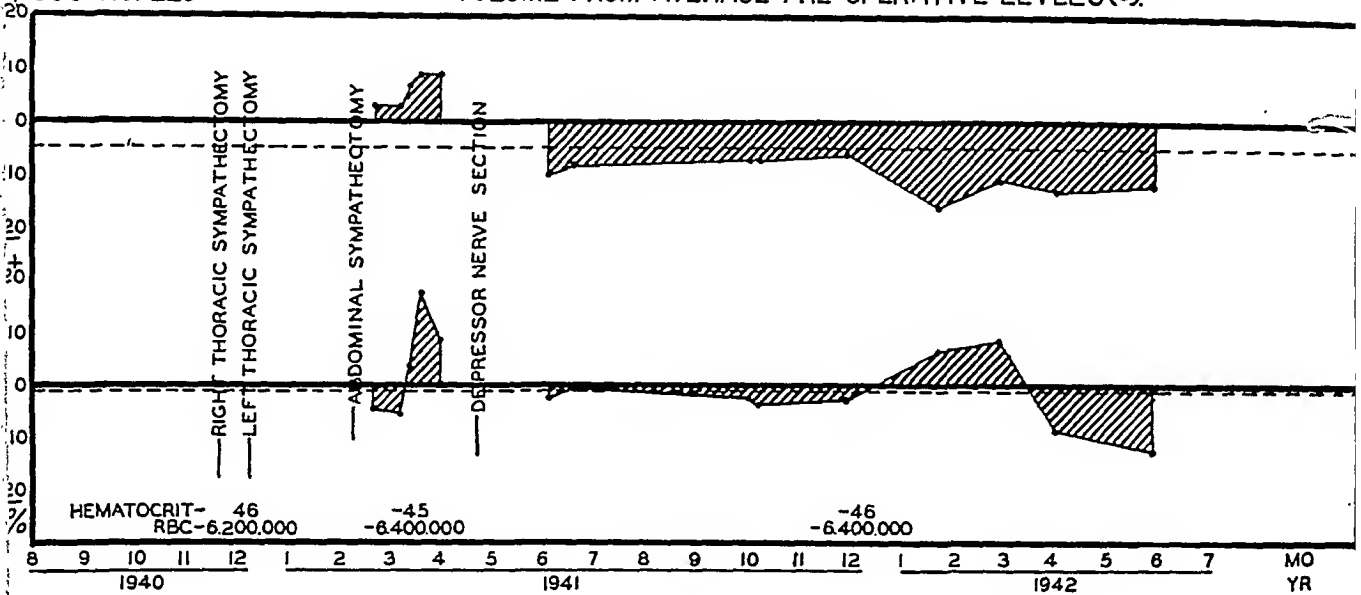
PERCENTAGE DEVIATION OF RED CELL MASS AND PLASMA  
VOLUME FROM AVERAGE PRE-OPERATIVE LEVELS(°).



10.—Fluctuations in red cell mass, plasma volume, red blood cell count and hematocrit during a two-year period of observation Dog 303 which was first subjected to proprioceptor depressor neurotomy and later to total paravertebral sympathectomy.

PERCENTAGE DEVIATION OF RED CELL MASS AND PLASMA  
VOLUME FROM AVERAGE PRE-OPERATIVE LEVELS(°).

DOG NO. 220

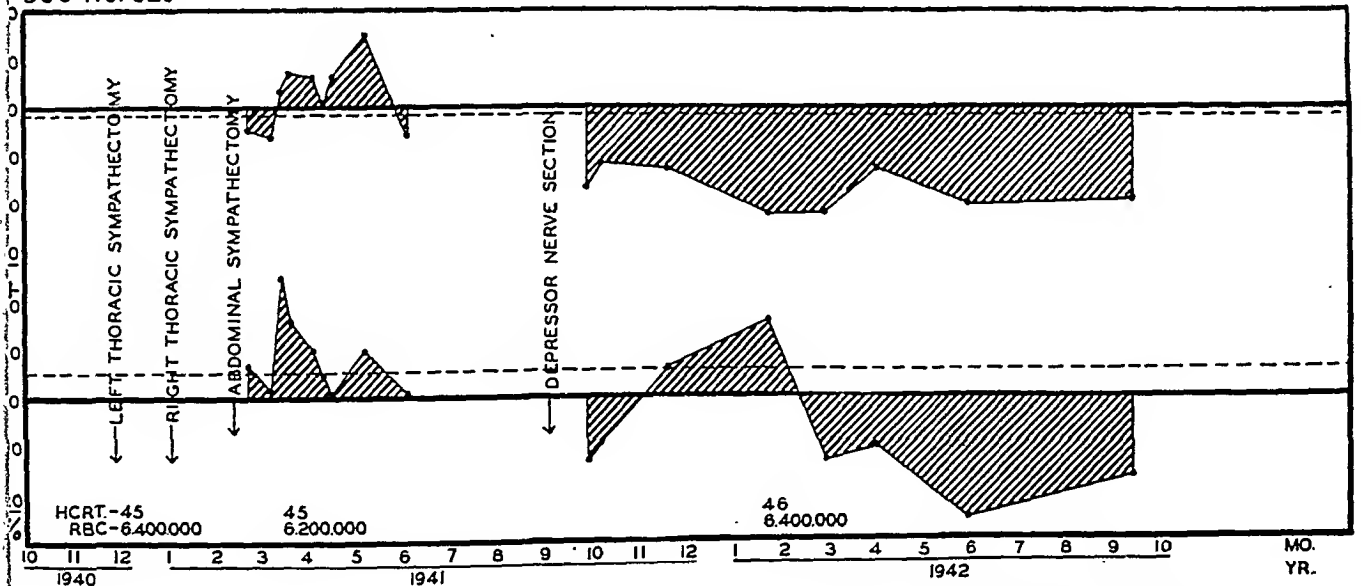


----- AVERAGE NORMAL FOR ALL DOGS

11.—Fluctuations in red cell mass, plasma volume, red blood cell count and hematocrit during a two-year period of observation of Dog 220 which was first subjected to total paravertebral sympathectomy and later to proprioceptor depressor neurotomy.

PERCENTAGE DEVIATION OF RED CELL MASS AND PLASMA  
VOLUME FROM AVERAGE PRE-OPERATIVE LEVELS(°).

DOG NO. 326



----- AVERAGE NORMAL FOR ALL DOGS

12.—Fluctuations in red cell mass, plasma volume, red blood cell count and hematocrit during a two-year period of observation of Dog 326 which was first subjected to total paravertebral sympathectomy and later to proprioceptor depressor neurotomy.



Before any surgery had been done, Dog No. 309 had an average plasma volume of 445 cc., red cell mass of 372 cc., total blood volume of 817 cc., hematocrit of 45 per cent and a red blood cell count of 6,000,000, with an average mean arterial blood pressure of 138 mm. of Hg. This dog was an 11-Kg. male of heavy build, so that in both plasma volume and red cell mass its average preoperative values expressed in terms of cubic centimeters/kilograms of body weight were somewhat lower than the average determined for the entire group of animals. In Figure 9, the average plasma volume and red

TABLE IV

Changes in blood pressure and body fluids of four dogs subjected to both proprioceptor depressor neurotomy and extensive paravertebral sympathectomy. Dogs 303 and 309 were first subjected to proprioceptor depressor neurotomy and then to extensive paravertebral sympathectomy while Dogs 220 and 326 were operated upon in reverse order.

DOG NO.		303	309	AVERAGE		220	326	AVERAGE		
DURATION OF OBSERVATION (months)	PRE-OP		1	2			5	2		
	AFTER PIN		6	6		AFTER SYM		2	4	
	AFTER SYM		12	12		AFTER PIN		12	12	
BLOOD PRESSURE (mm. Hg)	PRE-OP		138	138				134	141	
	AFTER	Total	279	198		AFTER	Total	107	122	
		% Change	+102	+43	+72		SYM	% Change	-20	-13
	AFTER	Total	189	220		AFTER		Total	186	184
		% Change	+37	+59	+48		PIN	% Change	+24	+50
PLASMA VOLUME (cc.)	PRE-OP		596	445				616	678	
	AFTER	Total	580	460		AFTER	Total	670	720	
		% Change	-3	+2	0		SYM	% Change	+9	+6
	AFTER	Total	518	454		AFTER		Total	556	557
		% Change	-15	+2	-4		PIN	% Change	-10	-18
RED CELL MASS (cc.)	PRE-OP		502	372				502	554	
	AFTER	Total	760	540		AFTER	Total	550	610	
		% Change	+51	+45	+48		SYM	% Change	+9	+10
	AFTER	Total	445	424		AFTER		Total	478	513
		% Change	-11	+13	+1		PIN	% Change	-5	-8
TOTAL BLOOD VOLUME (cc.)	PRE-OP		1098	817				1118	1250	
	AFTER	Total	1540	1000		AFTER	Total	1220	1350	
		% Change	+22	+22	+22		SYM	% Change	+9	+8
	AFTER	Total	985	878		AFTER		Total	1034	1070
		% Change	-12	+8	-2		PIN	% Change	-8	-13
"AVAILABLE" FLUID (cc.)	PRE-OP		2945	2088				2910	3563	
	AFTER	Total	5420	2650		AFTER	Total	5200	3750	
		% Change	+16	+27	+21		SYM	% Change	+10	+11
	AFTER	Total	5173	2650		AFTER		Total	5140	3883
		% Change	+8	+27	+17		PIN	% Change	+8	+15
TOTAL BODY WATER (cc.)	PRE-OP		7039	5296				7005	8244	
	AFTER	Total	6550	5600		AFTER	Total	7000	7900	
		% Change	-7	+6	0		SYM	% Change	0	-4
	AFTER	Total	8581	5608		AFTER		Total	6625	7842
		% Change	-6	+6	0		PIN	% Change	-5	-5

PIN - PROPRIOCEPTOR DEPRESSOR NEURECTOMY  
SYM - PARAVERTEBRAL SYMPATHECTOMY

cell mass for the entire group is indicated by a dotted line showing that this animal's plasma volume was 6 per cent lower than the group average, and its red cell mass was 15 per cent lower than the group average. Proprioceptor depressor neurotomy was carried out in November, 1940, and the animal studied for a period of six months. By this time the red blood cell count had increased to 8,000,000, the hematocrit to 55 per cent, the plasma volume remained unchanged but the red cell mass had increased 45 per cent and the total blood volume 22 per cent. The blood pressure then averaged 198 mm. of Hg., a 43 per cent increase over the preoperative level. This animal was then subjected to a complete paravertebral sympathectomy in three stages, as described above, the last stage being performed in September, 1941. The animal was then studied for an additional year, during which time the red blood cell count returned to 6,000,000, the hematocrit to 48 per cent and the plasma volume, red cell mass and total blood volume all gradually returned to the preoperative level.

Before surgery, Dog No. 303 had an average plasma volume of 596 cc., red cell mass of 502 cc., total blood volume of 1,098 cc., hematocrit of 46 per cent, red blood cell count of 6,000,000, and an average mean arterial blood pressure of 138 mm. of Hg. In Figure 10, it may be seen that this 12.3-Kg. male animal's plasma volume was 7 per cent lower than the group average, and its red cell mass was 4 per cent higher than the group average. Proprioceptor depressor neurotomy was carried out in November, 1940, and the animal studied for a six-months period. By this time the red blood cell count had increased to 9,000,000, the hematocrit to 58 per cent, the plasma volume remained unchanged but the red cell mass had increased 50 per cent and the total blood volume, 22 per cent. The mean arterial blood pressure then averaged 279 mm. of Hg., a 102 per cent increase over the preoperative level. This animal was then subjected to a complete paravertebral sympathectomy in three stages, as described above, the last stage being done in September, 1941. The animal was then studied for an additional year, during which time the red blood cell count returned to 6,000,000, the hematocrit to 48 per cent, and the plasma volume, red cell mass and total blood volume all fell to slightly below the preoperative level.

The changes in "available fluid" and total body water recorded in Table 4 were not considered to be of significant magnitude.

#### DISCUSSION AND FURTHER CONCLUSIONS

From these data it became apparent that the polycythemia which had been observed to follow proprioceptor depressor neurotomy disappeared completely after complete paravertebral sympathectomy and that proprioceptor depressor neurotomy was not followed by the development of polycythemia in two animals which had previously had a complete paravertebral sympathectomy. Further, the severe hypertension which follows proprioceptor depressor neurotomy was greatly diminished by complete paravertebral sympathectomy and proprioceptor depressor neurotomy caused only a moderate hypertension in two animals which had previously had a complete paravertebral sympathectomy.

The inescapable result of study of these foregoing observations was to relate positively the autonomic nervous system to the peripheral red cell mass. Proof of the exact nature of this relationship is not available in these data but they do have certain general implications. First, polycythemia was never observed to occur spontaneously in any of the 29 dogs included in this experiment. Of the animals subjected to surgery, the sympathectomized animals never developed polycythemia and four of the six sympathectomized animals had decreases in red cell mass to lower levels than were recorded for any other dogs in the series. Forty per cent of the dogs subjected to proprioceptor depressor neurotomy developed polycythemia, characterized by absolute increase in the red cell mass to levels far higher than were observed to occur in any other dogs in the series. Polycythemic animals subsequently subjected to sympathectomy lost their polycythemia and non-polycythemic sympathectomized animals subjected to proprioceptor depressor neurotomy did not become polycythemic even though they did become mildly hypertensive. Thus, polycythemia occurred only in animals which had intact sympathetic efferent tracts with absence of afferent depressor pathways. We considered loss of the afferent depressor mechanism to be the stimulus for the development of the polycythemia and the efferent sympathetic depressor pathways to be the route over which this stimulus exerted its effect, namely, through vasoconstriction. The finding in these proprioceptor depressor neurotomy animals of a polycythemia characterized by increase in red cell mass and in total blood volume, such as is seen in polycythemia rubra vera in man, led us to consider the rôle of vasoconstriction in this latter condition.

#### EFFECT OF EXTENSIVE PARAVERTEBRAL SYMPATHECTOMY ON POLYCYTHEMIA RUBRA IN MAN

A direct approach to this problem was possible since extensive sympathectomy has long been used as a treatment for essential hypertension in the human and the safety of the procedure has been well-established. Dr. K. S. Grimson was at that time performing complete paravertebral sympathectomy in this clinic for the treatment of human essential hypertension, and his results have since been published.<sup>19</sup> He agreed to carry out this procedure upon a selected case of human polycythemia rubra vera. The background for this experiment is obvious from the foregoing data, the experiment resting on the premise that if polycythemia rubra vera in man is similar to the polycythemia of proprioceptor depressor neurotomy in dogs, then ablation of the sympathetic efferent pathways should cause the polycythemia to disappear.

**Case Report.**—The patient chosen for this critical test was a 27-year-old male laborer, who was first seen in this clinic in May, 1941. At that time, he complained of extreme fatigue, shortness of breath and severe headaches, and stated that he had had "polycythemia vera" for three years. He had apparently been well until the early part of 1938, when he noticed that he began to tire easily and by midyear was forced to quit his work as a laborer. By this time, he had become short of breath and was severely troubled by persistent headaches. It had been noticed that his complexion had become quite florid. He consulted his local physician who made a blood count and diagnosed his condition as polycythemia rubra vera and recommended that the patient go to a nearby

clinic for treatment. The patient complied with his local physician's recommendations, and was thoroughly studied at the designated clinic, the work-up including blue dye determination of the plasma volume and the red cell mass. The diagnosis of polycythemia rubra vera was confirmed, and a program of venesection begun. From late in 1938 until his first visit here, two and one-half years later, the patient had been bled from 600 to 1,000 cc. of blood on the average of every two weeks. For the first week following bleeding he would have considerable remission in his symptoms but the following week all would rapidly return with as marked severity as before. As a result, he was confined to bed about half of the time and was not able to work.

The family history revealed that his mother and father, age 65 and 70, respectively, were alive and well, as were also four sisters and one brother. No family history of disease could be elicited. He had been married for nine years, and his wife, age 25, was in good health. He was the father of four girls and one boy, age 8, 6, 5, 4, and 2 years. One child had died at birth. He stated that he had scarlet fever at the age of 14, complicated by mastoiditis. This had left him with a left facial palsy. He had undergone tonsillectomy in 1933, and appendectomy in 1937. System inquiry added only the facts that he had recently developed a rather severe pain over the left anterior chest, which seemed to be relieved by bleeding, and that his memory had recently become markedly impaired.

Physical examination revealed the patient to be a well-developed and well-nourished man, weighing 70 kilograms. His temperature was 98° F.; pulse 68; respiration 16; and blood pressure 170/108 mm. of Hg. His face and hands were dull red in color. He was unable to hear a watch on his left side with the Weber test lateralized to the left and bone conduction greater than air conduction on the left. He had a complete left facial palsy to which he seemed well adjusted. Many dental caries were present and the pharynx was inflamed. Examination of the heart and lungs revealed no abnormality and aside from the scar of his previous appendectomy, examination of the abdomen revealed similar normal findings. The liver was not enlarged, and it was debatable whether the lower pole of the spleen could be palpated. The extremities presented no clubbing of the fingers or other abnormality. No lymphadenopathy was present. Rectal examination was not remarkable and neurologic examination revealed only normal findings, aside from the left facial paralysis. His urine was found to be acid in reaction with a specific gravity of 1.025, negative for albumin and sugar, and with a normal sediment. White blood cell count was 11,000, with 67 per cent polymorphonuclear neutrophils, 26 per cent small lymphocytes, three per cent monocytes and three per cent eosinophils. Red blood cell count was 5,790,000, and hemoglobin 14.0 Gm./100 cc., with slight polychromasia, anisocytosis and poikilocytosis. Reticulocytes were 0.6 per cent. The diagnosis of polycythemia rubra vera was made and the patient entered the hospital on the Hematology Service, May 20, 1941, for further study. T-1824 dye dilution measurement of the blood volume was carried out, at which time the following results were obtained: Weight 71.5 Kg. Total blood volume, 6,120 cc. Plasma volume 2,907 cc. Hematocrit 53 per cent. Total red cell mass, 3,212 cc. (51.9 cc. Kg. of body weight).

The patient remained in the hospital for two weeks, during which time his red blood count increased to 6,890,000 and his hemoglobin to 16.0 Gm./100 cc. His face became more deeply dull red in color and he began to develop a tight substernal sensation, and his headaches continued. Since the response of this patient to venesection had been poor it was elected to try roentgenotherapy to his long and flat bones. Between June 3, 1941, and July 24, 1941, he received eight treatments of 160 r in air each, directed to both femora, scapulae, anterior ribs and iliac blades. He received slight subjective relief following this therapy but on return to the clinic, December 15, 1941, he presented the same picture as before having received this therapy, and at that time his red blood cell count was 6,500,000 and his hemoglobin 16.7 Gm./100 cc. He again entered the hospital, December 20, 1941, for further observation. The eye consultants reported that his fundi showed bilateral papilledema with blurring and hyperemia of both disks. The veins

appeared fuller and more deeply red than usual. The arteries showed slight tortuosity and only slight increase in light reflex. A few focal spasms were present but crossing signs were not observed. The A-V ratio was 2:4 and no hemorrhages or exudates were present. They felt that the patient exhibited slight early hypertensive vessel changes and that the ocular fundus picture was compatible with a diagnosis of polycythemia rubra vera. The renal vascular disease consultants concurred in the diagnosis of very mild hypertension but did not believe that this hypertension was the basis for the patient's symptoms. They felt that the ocular fundus changes were due to increased intracranial pressure referable to the polycythemia and that the polycythemia was responsible for all of the patient's symptoms. The decision was then made to subject this patient to sympathectomy, not with the idea of treating his very mild asymptomatic hypertension but to see what effect sympathectomy would have on the course of his polycythemia.

Accordingly, January 9, 1942, a left paravertebral sympathectomy was performed, and on January 29, 1942, the same procedure was carried out on the right side. The operation was identical with that described for the animals used in this experiment, and has been elsewhere described by Grimson.<sup>20</sup> The extent of resection can be appreciated from study of the specimen removed at the first operation (Fig. 13). It included the left ganglionated sympathetic trunk from T-1 through L-2, together with the stellate and a portion of the celiac ganglia and all of the left splanchnic nerves. The amount of blood lost during these operative procedures was measured and the patient transfused with whole blood slightly in excess of the amount lost. At no time was venesection done. Careful studies of his blood volume and blood composition have been made repeatedly since the patient's first hospitalization here and are summarized in Chart 5 and Figures 14 and 15. The patient was discharged from the hospital, March 1, 1942, to be readmitted five, 23 and 39 months following operation for reevaluation of his status on each of these occasions. The last study was made in April, 1945. These data are, likewise, recorded in Chart 5 and Figures 14 and 15. At no time has a significant change been noted in his plasma volume. However, immediately following surgery, his total blood volume and red cell mass fell abruptly and then gradually increased, so that two years following operation the preoperative level had again been reached. His red blood cell count, hemoglobin and hematocrit changes have paralleled the change in total blood volume and red cell mass.

In spite of the fact that there has been a return of his blood picture to that of mild polycythemia, this patient has been completely relieved of all of his symptoms, and only in the past few months has he had any difficulty. He now notices that after long hours at work he develops a headache but he volunteers the information that this is not similar to, nor is it as severe as the headaches he had before his operation. He is now employed as an hospital orderly in his home town, and works strenuously 14 hours a day. At no time since his operations in January 1942 has he been bled, nor has he been subjected to any form of medicinal therapy for his polycythemia, and he now considers himself to be a well individual.

**DISCUSSION.**—In evaluating the results of extensive paravertebral sympathectomy in this case of human polycythemia rubra vera, one must be cautious, since spontaneous remission is known to occur in this disease. It was for this reason that this case was not reported at any earlier date. We have now had an opportunity to observe this patient for a period of more than three years since surgery was performed, and certain valid statements are now possible. First, there can be no question about the fact that the function of this man's peripheral constrictor mechanism was greatly reduced if not abolished by surgery. Evidence for this is the marked postural hypotension which he developed. As late as two months after his second stage syncope would occur if he abruptly changed from the lying to the standing

position, and it was not until five months after operation that this side-effect of the operation ceased to be a troublesome complication. The starch-iodine sweat tests illustrated in Figure 15, also indicate the extensive interruption of efferent sympathetic pathways that was brought about. Also, one would not question the fact that the blood volume and blood composition were

TABLE V

Effect of extensive paravertebral sympathectomy on the plasma volume, red cell mass, total blood volume, red blood cell count and hemoglobin of the case herein described.

DATE	TOTAL BLOOD VOLUME	RED CELL MASS	PLASMA VOLUME	HEMATOCRIT	RBC	Hb
12/22/41	6120	3212	2908	53	6,400,000	16.7
1/5/42	5821	3085	2736	53		
1/9/42	5350	2889	2461	54		
1/9/42	LEFT THORACIC SYMPATHECTOMY					
1/16/42	4800	2163	2637	45	4,910,000	14.7
1/25/42	5250	2430	2820	46		
1/29/42	RIGHT THORACIC SYMPATHECTOMY					
2/5/42	5150	2270	2880	44	5,270,000	15.3
2/21/42	4400	1940	2460	44		
6/6/42	5100	2680	2420	52	6,310,000	17.6
6/11/42	5040	2620	2420	52		
12/13/43	5500	3130	2370	57	5,790,000	18.0
3/30/45	5540	3160	2380	57	6,240,000	19.8
4/4/45	5500.	3197	2303	58		

other than normal as late as two months following operation, in spite of the fact that a careful measurement and estimation of the blood loss attendant with his operative and postoperative period were made and that this loss was replaced by transfusions of whole blood. Lastly, one must accept the fact that this patient has remained asymptomatic and has become capable of strenuous prolonged labor without resort to any form of treatment for his disease. The fact still remains, however, that in the first two years following operation there was a gradual elevation of his blood volume and blood composition to levels not dissimilar to those observed before operation, but in

the third postoperative year only slight further increases were recorded. Further, this recurrence of polycythemia has not been attended by recurrence of subjective symptoms, nor has it in any way incapacitated the man, or required further therapy.

It was obvious to us that some of the above observations had to be further explored if a positive relationship between peripheral vasoconstriction and

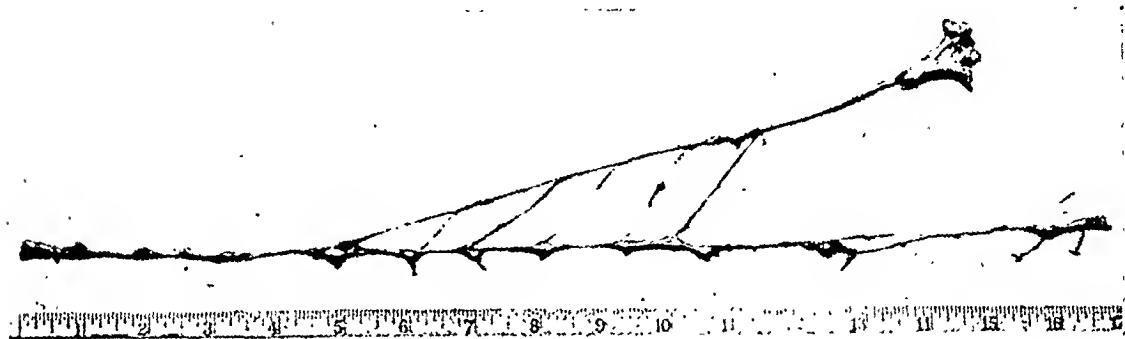


FIG. 13.—Photograph of a specimen obtained at the time of the first operation on the patient herein described. At the left is the left stellate ganglion and at the upper right, a major part of the left coeliac ganglion. At the bottom right are the first and second lumbar ganglia of the sympathetic trunk. The remainder of the specimen consists of the left ganglionated sympathetic trunk and splanchnic nerves.

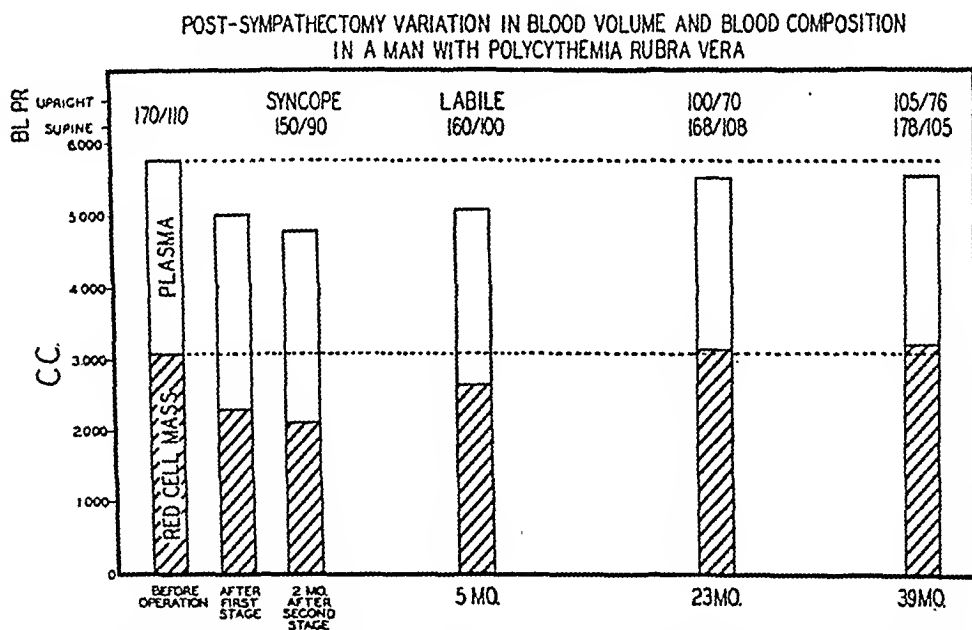


FIG. 14.—Correlation of the postsympathectomy alterations in blood volume and blood composition and supine and upright blood pressures observed in the patient herein described.

polycythemia was to be maintained. In the experimental animals, polycythemia required intact sympathetic efferent fibers for its existence, yet, in this patient asymptomatic polycythemia had recurred following extensive paravertebral sympathectomy. From our experience, with both dogs and man, we knew that maintenance of complete interruption of sympathetic efferent pathways was not possible. Thus, while complete paravertebral sympathectomy actually destroys these pathways and results in vasodilatation, the effect is not permanent, and a gradual restoration of sympathetic control develops. We routinely find profuse proliferation of nerve fibers through the scar of the extrapleural space when autopsy examination of pre-

viously sympathectomized animals is carried out remote from the time of operation. Further, dogs which have been previously sympathectomized are not completely protected from the development of hypertension when subsequently subjected to proprioceptor depressor neurotomy, although the hypertension which does develop is always slight or moderate as compared to the hypertension which follows proprioceptor depressor neurotomy in the normal dog. Again, although the hypertension which follows proprioceptor depressor neurotomy disappears, or is greatly diminished, following extensive paravertebral sympathectomy, there is a gradual return of the blood pressure to high levels, though never so high as before sympathectomy in these animals. In man, postsympathectomy postural hypotension is always most severe immediately after operation, and it becomes gradually and progressively less marked as time goes by, but is usually demonstrable even late after surgery. Lastly, immediately following sympathectomy in man, sweating does not occur in the denervated areas of skin, but there is a gradual and progressive recovery of this function. This phenomenon can be most easily recorded by the use of starch-iodine sweat tests. As part of the study of the above-described case, frequent lying, sitting and standing blood pressure readings were made on each hospital admission as well as starch-iodine sweat tests. These data are summarized in Figures 14 and 15. The average of all preoperative blood pressure readings on this man was 170/110 mm. of Hg., with no demonstrable evidence of postural effect.

Each blood pressure reading recorded in Figure 14 represents the average of all designated readings made during each hospital stay. As late as two months after his second stage his blood pressure could not be obtained in the upright position. By five months, it was extremely labile and at very low levels. At 23 months after operation, his average standing pressure was 100/70 mm. of Hg. and at 39 months, 105/76 mm. of Hg. The average supine blood pressure readings, likewise, show a gradual return to approximately the preoperative levels. A closely parallel change was observed in this patient's sweating function, and is pictorially presented in Figure 15. Here one observes the gradual and progressive increase in both the area of skin in which sweating occurs and in the amount of sweating which occurs in these areas. The decrease in postural hypotension, return of supine blood pressure level, and the increase in sweating ability were interpreted to mean recovery of sympathetic efferent function in this man, presumably mediated through regeneration of sympathetic efferent fibers. As may be seen from Figures 14 and 15, these changes parallel exactly the observed changes in blood volume and blood composition. Thus, the recurrence of the polycythemia, when viewed in conjunction with these observations on sympathetic efferent phenomena, serve not to disprove the positive relationship between vasoconstriction and polycythemia but to further support this view.

Much investigative work will have to be done before the implications of this report can become firmly established, yet one cannot but be impressed by the likelihood of autonomic nervous system control of certain functions of the bone marrow. This study has been conducted by alteration of this rela-



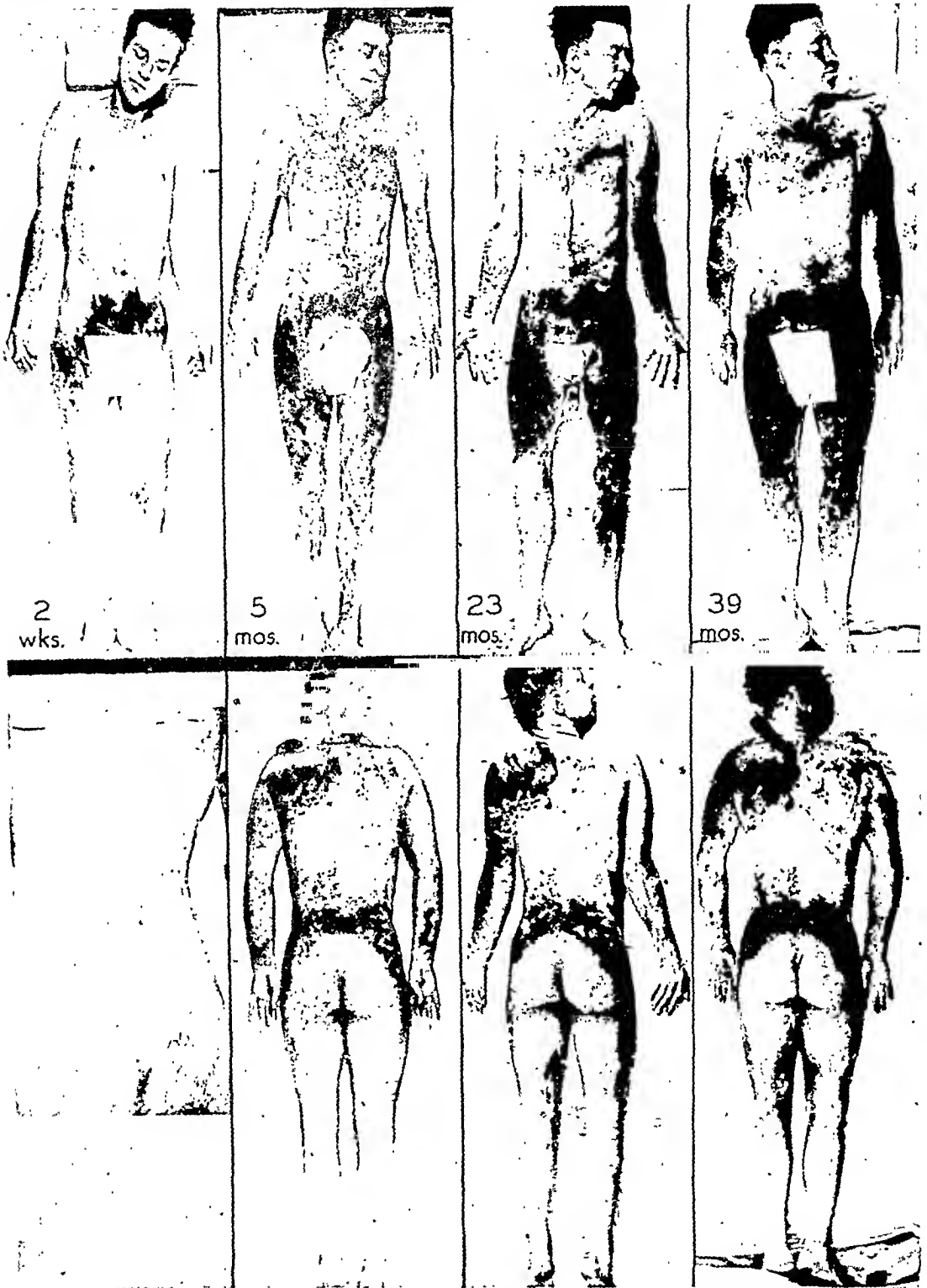


FIG. 15.—Starch-iodine sweat tests at one-half, five, twenty-three and thirty-nine months following extensive paravertebral sympathectomy in the patient herein described. Progressive recovery of his sweating function is seen.

tionship remote from the zone of ultimate effect, the bone marrow, and the results obtained have been the observed changes in an equally remote area, the peripheral blood. Yet, all of our observations lead us to the impression that the sympathetic efferent fibers do control erythropoiesis and, to us, the most likely basis for this control lies in the state of vasoconstriction or vasodilatation of the presinusoidal vessels of the bone marrow. We know from

countless observations that any condition characterized by lack of oxygenation of the systemic arterial blood will, likewise, present polycythemia as a result of hyperactivity of the myeloid elements of the marrow, presumably due to the presence of the unoxygenated blood in the marrow. The most generally accepted and most plausible theory of normal production of the red cell is that there is intermittent constriction and dilatation of vessels leading to the sinusoids of the marrow and that during states of presinusoidal vasoconstriction, the blood of the sinusoids so affected is isolated from the general circulation. Low oxygen tension develops in these sinusoids and acts as a stimulus for red cell production. It is our impression that the tone of these presinusoidal blood vessels is under the control of the sympathetic efferent nerves in states of health and that the fundamental defect in many cases of polycythemia rubra vera is likely to be a more persistent vasoconstriction of presinusoidal blood vessels as a result of overactivity of the sympathetic nerves to these vessels. Supporting evidence for this view is the study of blood lactate levels following exercise in patients with polycythemia rubra vera.<sup>21</sup>

In patients with this disease, whether they are under treatment or not, exercise causes a fall in blood lactate whereas exercise in normal individuals is followed by a rise in blood lactate. A possible explanation for this is that there is decreased blood flow through the tissues in polycythemia rubra vera, resulting in an high resting blood lactate and an accumulation of lactate in the tissues, so that exercise with vasodilatation would cause a fall in the blood lactate level. The work of Davis in the production of polycythemia by the administration of various vasoconstrictor drugs indicates that vasoconstriction is capable of producing polycythemia.<sup>22</sup> The frequent occurrence of mild hypertension in polycythemia rubra vera has generally been attributed to increased blood viscosity or has been regarded as being due to the coincidental existence of essential hypertension. In a series of 163 cases of this disease, Tinney has reported a systolic blood pressure of more than 150 mm. of Hg. in 40 per cent, and of more than 180 mm. of Hg. in 9 per cent of the cases.<sup>23</sup> It has frequently been observed that the blood pressure does not always return to normal after therapeutic measures have caused the blood picture to approach normal levels. This is further presumptive evidence for the existence of vasoconstriction in these individuals.

Neurologic manifestations in polycythemia rubra vera are very common and intracranial lesions are generally regarded to be of common occurrence in this disease. The almost universal attitude toward this relation is that the nervous system lesion is always secondary to the polycythemia. Our experimental neurogenic polycythemia described above was produced by section of afferent cervical depressor pathways, the carotid sinus and cardio-aortic nerves, which caused uninhibited activity of vasoconstrictor impulses over the efferent sympathetic mechanism. Although the point of origin of the imbalance of this mechanism in our experiments was at the level of the afferent depressor mechanism, it is conceivable that there could be conditions in which the central nervous system portion of this reflex arc could be

influenced either directly by mechanical, inflammatory or neoplastic disease or indirectly through connections with other areas of the central nervous system. Experimentally, only meager efforts have been made to produce polycythemia by manipulations in the region of the diencephalon and the results of this work are not convincing.<sup>24, 25</sup> The report of Carpenter, *et al.*,<sup>26</sup> of two cases of hemangioblastoma of the cerebellum with associated absolute polycythemia, which in each case disappeared following extirpation of the tumor could well represent instances of mechanical stimulation of the central connection of this reflex arc which is here under study. It is of interest that one of these cases presented with a blood pressure of 160/120 mm. of Hg. and that this moderate hypertension disappeared after operation. Another similar case has more recently been reported by Walker.<sup>27</sup> A rather substantial volume of clinical literature has accumulated in the past two decades causally relating polycythemia to primary lesions of the brain stem, but these reports are so incomplete, either from the standpoint of accurate diagnosis or inadequacy of anatomic and pathologic verification of findings, that they serve to confuse rather than clarify the problem. This literature has been adequately reviewed by Da Rin and Costa,<sup>28</sup> Ferraro and Sherwood,<sup>29</sup> and Lucia and Marasse,<sup>30</sup> and will not here be repeated.

#### SUMMARY

1. Using dilution methods, the following average normal values were observed in 29 normal dogs: Plasma volumes 54 cc. Kg. of body weight. Red cell mass, 47 cc. Kg. of body weight. Total blood volume 101 cc. Kg. of body weight. "Available fluid," 279 cc. Kg. of body weight. Total body water, 640 cc. Kg. of body weight.

2. Following proprioceptor depressor neurotomy six of 13 animals developed absolute polycythemia and all became hypertensive.

3. Following extensive paravertebral sympathectomy, four of six animals developed a significant decrease in red cell mass and total blood volume.

4. Two dogs with chronic peripheral vasoconstriction which had resulted in persistent marked hypertension and persistent marked absolute polycythemia were subjected to extensive paravertebral sympathectomy which resulted in decrease in the blood pressure to moderate hypertensive levels and disappearance of the polycythemia.

5. Two dogs with chronic peripheral vasodilatation, which had resulted in transient minimal hypotension, were subjected to proprioceptor depressor neurotomy, which resulted in the gradual appearance of a moderate hypertension but polycythemia was not observed to occur.

6. The case of a 27-year-old man with intractable polycythemia rubra vera is presented, and the effect of extensive paravertebral sympathectomy recorded. Thirty-nine months after operation he is asymptomatic, without further therapy, and is able to perform prolonged strenuous labor. The postoperative change in his blood volume and blood composition has been related to sympathetic efferent function.

7. The relationship of these data to the normal and abnormal physiology

of red blood cell formation by the bone marrow is discussed, and the meager experimental literature reviewed.

## CONCLUSION

By means of proprioceptor depressor neurotomy a form of absolute polycythemia has been experimentally produced in dogs, and it has been shown that this form of experimental polycythemia disappears following extensive paravertebral sympathectomy. Support is given to the theory that the normal and some abnormal formation of red blood cells by the bone marrow is under the control of the sympathetic nervous system through its regulation of the caliber of the presinusoidal vessels of the marrow. The theory is advanced that some cases of polycythemia rubra vera in man are due to constriction of the presinusoidal blood vessels of the bone marrow and extensive paravertebral sympathectomy is proposed as treatment for this disease. The successful result of treatment of a man with polycythemia rubra vera by extensive paravertebral sympathectomy is recorded.

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# PRINCIPLES AND PRACTICE OF PENICILLIN THERAPY IN DISEASES OF THE NERVOUS SYSTEM

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PENICILLIN is the most powerful chemotherapeutic agent now known, and its value in infections of the nervous system is well-recognized. However, its administration for optimal results in the treatment of nervous diseases is not yet standardized. This is, in part, due to the fact that most emphasis has been placed upon the antibiotic effect of the drug on the invading organism and little attention paid to its pharmacologic effect upon the brain and spinal cord, which are equally important factors in arriving at a rational therapeutics. In part, it is due to a lack of exact knowledge of the distribution and dispersion of the drug in the spinal fluid after systemic and intrathecal administration. The accumulated clinical experience in the use of penicillin augmented by fundamental studies of these factors should give a more rational basis for the therapy of diseases of the nervous system.

## PENICILLIN SENSITIVITY OF THE ORGANISMS

In general, penicillin is effective against gram-positive aerobic or anaerobic organisms, and relatively innocuous to the gram-negative organisms. However, within the group of gram-positive organisms a wide range of sensitivity is found, and even strains of the same organism may exhibit variations in susceptibility to the antibiotic action of penicillin. For this reason it is essential to know not only the type of infecting organism but its penicillin sensitivity. Several tests, modifications of one of the methods of penicillin assay, have been suggested as a means of determining the relative susceptibility to penicillin of an organism.<sup>8, 3</sup> *In vitro* and *in vivo* experiments have demonstrated that at certain critical penicillin concentrations any given susceptible organism may be destroyed within a certain time. With lesser amounts of penicillin the organisms will grow indefinitely.<sup>21</sup> In the case of the *Streptococcus haemolyticus* doubling of this critical penicillin concentration roughly halves the time necessary for killing the organisms. But a still further greater concentration does not appreciably shorten the lethal period. From *in vitro* experiments the critical concentrations for the more common organisms found in infections of the central nervous system<sup>21</sup> have been determined (Table I.)

There is no reason to believe that these concentrations are not equally applicable to the spinal fluid. In general, then, one might conclude that a concentration of penicillin in the cerebrospinal fluid of 0.036 Oxford units/cc. for a period of at least three hours should be adequate to destroy *Streptococcus haemolyticus* organisms. However, two other factors must be considered.

In the first place, the number of organisms present in the meninges may be so great that the effectiveness of the penicillin is decreased. Probably more important is the fact that organisms may be introduced into the sub-arachnoid space from foci which are inaccessible to the drug. For this reason

TABLE I  
CRITICAL CONCENTRATIONS FOR THE MORE COMMON ORGANISMS  
FOUND IN INFECTIONS OF THE CENTRAL NERVOUS SYSTEM

Organism	Time Exposed	Concentration of Penicillin in Blood Units/Cc.
<i>Streptococcus haemolyticus</i> ( <i>Meningococcus</i> approx. the same 1).....	3 hrs.	0.036
<i>Staphylococcus aureus</i> .....	3 hrs.	0.066
<i>Pneumococcus</i> , Type I (Types III and VII approx. the same 1).....	3 hrs.	0.078
<i>Streptococcus viridans</i> .....	3 hrs.	1.50

the theoretic exposure time necessary for killing is inadequate in practice. However, the effective concentrations for the various bacteria give an indication of the relative amount of penicillin necessary to control an infection due to that particular organism.

#### MODES OF ADMINISTERING PENICILLIN

*Systemic Administration.*—Although the earlier investigators<sup>13, 10, 20</sup> were unable to detect penicillin in the spinal fluid there is accumulating evidence that it may enter the spinal fluid and attain an adequate bacteriostatic concentration after parenteral administration.<sup>4, 24</sup> Under normal conditions of the meninges in experimental animals and man, penicillin has been detected in the spinal fluid in only a very small percentage of cases.<sup>11</sup> If the meninges were irritated by bacterial, chemical or physical agents, however, penicillin was found to pass through readily to the spinal fluid. Whereas, intravenous administration of sufficient penicillin to produce blood levels of 23.5–32.5 Oxford units per cc. did not cause any of the drug to be detected in the spinal fluid of the Macaque monkey, after inducing a meningeal reaction by cerebral concussion or by the intrathecal injection of air, heparinized blood or bacteria, from 0.17–0.78 Oxford units per cc. of penicillin were usually found in the spinal fluid. Occasionally concentrations as high as 10–50 per cent of a blood level of 10–25 units per cc. were found. In man penicillin given intramuscularly six to eight hours after pneumo-encephalography may be detected in the spinal fluid within an hour. In animals with meningitis the penicillin may be detected in the spinal fluid for as long as three hours after its systemic administration. Rammelkamp and Keefer<sup>10</sup> found that the absorption of the penicillin from the cerebrospinal fluid was more rapid in patients suffering from meningitis than in normal subjects.

On the basis of these studies it seems that a concentration of penicillin adequate for the more sensitive organisms may be maintained in the spinal fluid by systemic administration of the drug every three hours.

*Intrathecal Administration.*—Because a sufficiently high concentration to kill the bacteria more resistant to penicillin probably cannot be obtained by

systemic administration, supplemental intrathecal injection is necessary in some cases. The ideal route of intrathecal administration would be one by which the penicillin would be equally distributed in the subarachnoid space, with the highest concentration, if a gradient were present, about the foci of infection. An understanding of the dispersion and distribution of penicillin in the spinal fluid when given by lumbar, cisternal and intraventricular routes is essential to determine the optimum technic.

When the drug is injected into the lumbar subarachnoid space of man its dispersion throughout the spinal fluid is quite slow. Within one to two hours the drug can usually be detected in the cisternal fluid, reaching a peak concentration in two to six hours of 0.4 per cent/cc. of the amount injected. However, in some cases the penicillin is apparently absorbed before it can reach the cisterna magna, for in several instances in man no penicillin has been detected in the cisternal fluid after the lumbar injection of 20,000 Oxford units, and in one case after the injection of 30,000 Oxford units.<sup>11</sup> The concentration of the drug in the lumbar region rapidly falls, so that four hours after injection it is usually under 0.5 per cent/cc. of the amount injected. However, an adequate bacteriostatic concentration is maintained for approximately 24 hours (Chart I).

When the drug is injected into the cisterna magna of man the concentration in the lumbar subarachnoid fluid rapidly increases so that two hours after the injection it is approximately 1 per cent/cc. of the amount given. In four hours it has decreased to one-half that concentration. After that time the concentration curves of the lumbar spinal fluid, following lumbar and cisternal injection of penicillin, are practically identical (Chart 2). In dogs the ventricular concentration after cisternal injection is higher than after lumbar injection. Presumably the concentration in the basal cisterns and subarachnoid space over the convexity of the brain is also higher.

Intraventricular injection of penicillin in man should be followed by rapid and widespread dispersion of the drug if it follows the pattern of diffusion of dyes injected intraventricularly. Because a perforation in the skull is necessary this mode of administration is undesirable as a routine method of giving penicillin.

From the standpoint of dispersion of the drug, the injection of penicillin into the cisterna magna is the best route available. However, cisternal puncture is not without danger, even in experienced hands, so that usually it is wise to sacrifice the somewhat better distribution of the drug, for the greater safety of lumbar injection.

#### DOSAGE

If an attempt is to be made to control the infection of the central nervous system by systemic administration, the penicillin must be given in relatively large amounts (40,000, or more, units) at three-hour intervals or continuously intravenously. If the condition does not respond to this dosage, intrathecal administration of the drug is desirable. In the usual case 10,000

Oxford units of penicillin dissolved in 5–10 cc. of distilled water or normal saline and injected intrathecally is quite sufficient to maintain an adequate bacteriostatic level in the spinal fluid for 24 hours. Larger amounts of penicillin may give rise to severe reactions.<sup>19, 22</sup> Injections at 12-hour intervals are likely to be accompanied by prolonged fever and signs of meningeal irritation.<sup>22</sup>



FIG. 1.—Photographs showing the reactions of a monkey ten minutes after injection of 20,000 Oxford units into the lumbar subarachnoid space. That the animal is experiencing peri-anal paresthesias seems evident.

#### REACTIONS TO INTRATHECAL INJECTION OF PENICILLIN

Fortunately, there is relatively little reaction of the meninges to the injection of penicillin.

*Pleocytosis.*—The more purified products now available cause only a slight pleocytosis, usually less than 100 cells, the majority of which are



lymphocytes, with or without a slight increase in protein. There appears to be some variation in amount of the impurities in the products manufactured by different companies. From the injection of some preparations a marked sterile meningitis is produced but this is rare at the present time. Usually there is no systemic reaction to amounts of 10,000 units or less.

*Radiculitis.*—Although relatively small doses produce the effects mentioned above, larger doses may cause serious and alarming sequelae. In monkeys 20,000 Oxford units in 1 cc. of normal saline, injected into the lumbar subarachnoid space has produced severe reactions<sup>11</sup> (Fig. 1). Within ten minutes of the injection, the animal would begin to inspect, rub, and then scratch vigorously his tail and peri-anal region. This behavior might persist for one-half to one hour. It seemed probable that the animal was experiencing paresthesias. Although the monkey appeared to be well the next day there is clinical evidence that such radicular reactions may not be so fleeting.

We have seen, in consultation, an adult male who, as a complication of a cholesteatomatous otitis media developed severe symptoms and signs of meningeal irritation. A radical mastoidectomy was performed. The spinal fluid the following day, although sterile, contained 3,000 cells. At this time 100,000 units of penicillin in 5 cc. of saline were given intrathecally. Twelve hours later the patient complained of urinary retention and paresthesias in the saddle region. A marked hypesthesia in this area was found. The urinary and sensory disturbance gradually decreased but when the patient attempted to walk two weeks after operation his legs were weak and unsteady. Over a period of three months the disturbance gradually cleared up. To complicate this case it was found that the patient had had a positive Wassermann reaction in the blood 12 years previously, although his spinal fluid reaction was negative. The patient neglected any antiluetic therapy and at the time of hospitalization for his above mentioned complaints his blood Wassermann reaction was still 4 plus. The spinal fluid Wassermann, however, was negative and the colloidal gold curve was normal.

It seems, therefore, that this case should be considered a sacral radiculitis resulting from penicillin therapy. That the systemic luetic infection was the main factor in the complication seems improbable. Similar reactions have been reported in individuals not suffering from syphilis.<sup>26</sup> In retrospect, the intrathecal penicillin therapy used in this patient seems rather severe because an actual infection of the meninges was never established and the patient's condition, general and local, did not appear to be severe enough to warrant the large dosage.

*Arachnoiditis.*—Occasionally a localized arachnoiditis at or near the site of injection of intrathecal penicillin has developed. It is difficult to be certain that this condition is entirely due to the drug, for the penicillin in the cases cited was given for a meningitis, which rarely has a localized arachnoiditis as a sequela.

*Cerebral Reactions.*—Besides toxic reactions on the spinal cord, large doses

of penicillin administered intrathecally may induce cerebral reactions in the form of convulsions, coma and even death.<sup>27, 28</sup> In man, apparently, a relatively large amount of penicillin may be tolerated, but in the monkey 20,000 units injected in the lumbar subarachnoid space has induced epileptic attacks, coma and death within 12 hours. Neymann, *et al.*,<sup>10</sup> however, has reported two severe reactions with convulsive manifestations, coma and death from the administration of 50,000 Oxford units in the cisterna magna for the treatment of dementia paralytica. Although Neymann, *et al.*, suggests that these manifestations are due to impurities in the penicillin, animal experimentation<sup>28</sup> has shown that pure crystalline penicillin has identical convulsive properties to commercial preparations. Moreover, the convulsive and antibiotic factors appear to be approximately equally affected by various means of inactivation. We believe that it is the penicillin itself which is responsible for the convulsive manifestations.

Convulsive reactions are more likely to occur following intraventricular injection of the drug or its topical application to the cerebral cortex. In dogs and monkeys approximately 500 Oxford units so administered is sufficient to induce epileptic manifestations.<sup>11</sup> Although man can tolerate much larger doses in either site, convulsive reactions have been reported. Probably many more have occurred, but have been considered the result of the primary condition for which the penicillin was being administered. One of the authors knows of several cases in which convulsive seizures developed within five minutes to nine hours after instillation of penicillin into a cerebral abscess or brain sinus. That they were the result of the therapy is difficult to determine because other organic pathologic conditions equally potentially epileptogenic were present. Yet the patients had had no previous seizures, although their pathologic lesion had been present for months.

#### PENICILLIN THERAPY IN SPECIFIC NERVOUS CONDITIONS

Penicillin therapy has been found of great value in a wide variety of infections of the central nervous system. Some of these may be effectively treated by other chemotherapeutic agents; others respond only to penicillin.

*Meningitis.*—The meningitides, as a group, have responded very well to penicillin therapy. When a case is suspected of being meningitis, the therapy of choice would appear to be penicillin since it is effective against a greater number of organisms than any other chemotherapeutic agent. If the diagnostic spinal puncture yields a cloudy fluid, the immediate intrathecal injection of 10,000 Oxford units of penicillin seems advisable. This will induce and maintain an antibiotic concentration of penicillin in the cerebrospinal fluid for approximately 24 hours. During that time the infective agent may be determined; its penicillin-resistance estimated, and the advisability of further systemic and/or intrathecal therapy considered. If the patient does not improve clinically within 24–48 hours a change to, or the addition of, sulfonamides may be wise. Intracisternal injection of penicillin will give a much

better dispersion of the drug than the lumbar injection and may be advisable if a temporary improvement begins to regress. Relapses probably indicate a focus which is loculated and not accessible to the mode of administration employed. Intraventricular injection may eliminate such foci. However, at times pneumo-encephalography or ventriculography is needed to locate a loculated leaking subarachnoid or subdural abscess.

*Meningococcic Meningitis.*—This type of meningitis has responded very well to sulfonamide therapy—the recovery rate being 89–98.7 per cent with this form of treatment. In fact, Keefer<sup>12</sup> states that sulfadiazine is the drug of choice in these infections, although he believes that if improvement

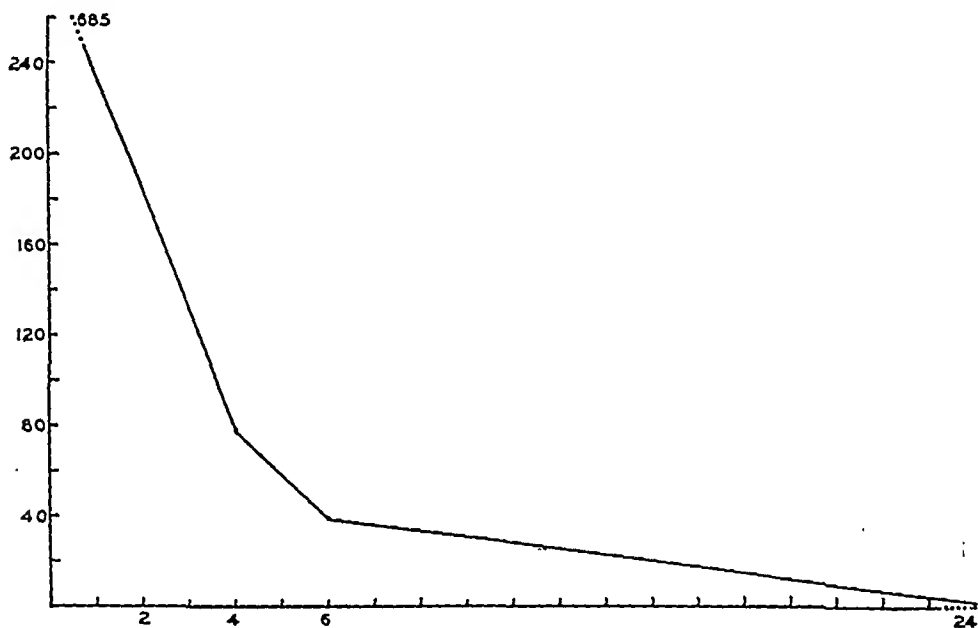


CHART 1.—Showing the concentration of penicillin in the lumbar spinal fluid of man (average of nine cases) after injection of 20,000 Oxford units by lumbar puncture. (The ordinates represent Oxford units of penicillin per cc.; the abscissa hours after injection).

is not apparent within 24–48 hours penicillin should be used. Rarely the two drugs may be required in combination. Since the meningococcus is quite sensitive to penicillin, intramuscular administration of penicillin is frequently adequate to control the disease.<sup>24</sup> Craig, *et al.*,<sup>5</sup> and Meads, *et al.*,<sup>15</sup> question the need for intrathecal penicillin in meningococcic meningitis.

*Streptococcic Meningitis.*—Although Kolmer<sup>14</sup> states that sulfonamide therapy is superior to penicillin in streptococcic meningitis, in some instances the latter drug has proven more successful. Many strains of streptococci are quite sensitive to the drug. In general, however, intrathecal administration of the drug as well as systemic injection will be required. When the meningitis is secondary to a focus in or about the skull, surgical treatment of that focus is essential to a successful outcome.

*Staphylococcic Meningitis.*—Since this type of infection is less amenable to sulfonamide therapy, penicillin is particularly desirable in its treatment.

Although only a few cases of staphylococcus meningitis have been reported as treated by this drug<sup>7</sup> the results have been quite satisfactory. Both systemic and intrathecal administration of penicillin appear to be desirable.

*Pneumococcic Meningitis.*—This type of meningitis formerly was uniformly fatal. Sulfonamide therapy reduced its mortality; penicillin has still lowered it to approximately 50 per cent.<sup>14</sup> Since the pneumococcus is more resistant to penicillin than the streptococcus and staphylococcus, a high con-

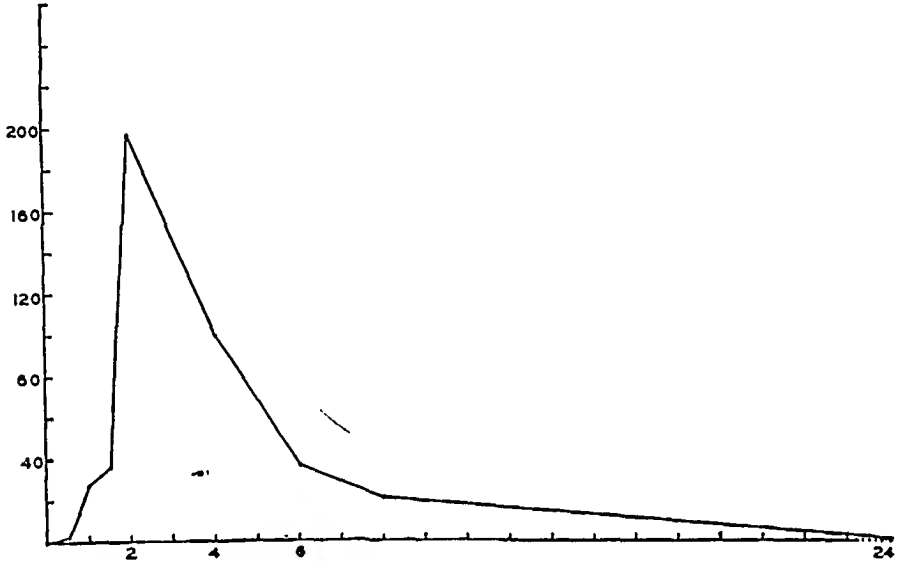


CHART 2.—Showing the concentration of penicillin in the lumbar spinal fluid of man (average of nine cases) after injection of 20,000 Oxford units by cisternal puncture. (The ordinates represent Oxford units of penicillin per cc.; the abscissa hours after injection).

centration is necessary in the spinal fluid. Administration should, therefore, be both systemic and intrathecal. The systemic route is important since many of these cases have a bacteriemia.<sup>17</sup> Probably penicillin combined with sulfadiazine is superior to either drug alone. In some cases intraventricular injections of penicillin may be necessary, particularly if an hydrocephalus develops due to fibrosis about the foramina of Luschka and Magendie at the base of the brain.

*Compound Fractures of the Skull with Brain Damage.*—The mortality from penetrating war wounds of the skull and brain has been materially decreased by the use of penicillin. Although the evidence that penicillin prophylactically decreases infection is not satisfactory,<sup>6</sup> there is no doubt that in the presence of infection penicillin allows surgical procedures to be carried out which would otherwise be impossible. It is no substitute for débridement and all authors emphasize that dirt, hairs, bone chips, necrotic brain, blood and foreign bodies must be removed if the full effect of the drug is to be realized. Cairns<sup>2</sup> advocates the application of penicillin powder (5,000 Oxford units of penicillin per gram of one of the sulfonamides) to recent brain and scalp wounds with primary closure. In older wounds he advises

irrigation of the wound through a tube twice daily for three to five days. The policy of many surgeons is to débride the wound radically, dust in sulfadiazine, and/or instill 5,000–20,000 units of penicillin, dry or in aqueous solution, and close the wound without drainage, giving systemic penicillin for several days to a week. The great majority of wounds so treated will heal *per primam*. If the cerebral wound has penetrated into the ventricle, intrathecal penicillin may be advisable.

*Brain Abscess.*—Penicillin and sulfonamide therapy have materially changed the clinical picture of brain abscess. Whereas, formerly the symptoms of acute cerebral infection were present for days or weeks before the abscess became encapsulated, now little clinical evidence of an encephalitis is seen. Any patient with a compound wound of the head who continues to complain of headache and/or whose wound is slow in healing must be suspected of harboring an intracranial abscess. Systemic penicillin in doses of 200,000–300,000 units daily should be given before the abscess is evacuated or extirpated. Intrathecal penicillin may also be advisable if meningeal signs are present. Although injection of penicillin into the abscess cavity after aspiration of pus may sterilize the cavity, usually drainage or extirpation is required before the cavity can be obliterated. At the time of drainage instillation of 1,000–20,000 Oxford units of penicillin in solution or in a vaselined pack may decrease the likelihood of spread of infection. If meningitis has been preëminent, intrathecal administration of penicillin may be necessary. The systemic penicillin should be continued for at least a week after drainage of the abscess.

*Spina Bifida.*—Infected meningoceles and meningomyeloceles usually respond well to local injection of penicillin (probably 1,000 to 10,000 Oxford units injected every day or two into the sac through normal skin is the optimal dosage). Not only does the infection subside but the thin ulcerated parchment-like skin over the sac heals, becomes thickened and shrinking, decreases the size of the elevated mass. The scar is so firm that surgical repair may not be required.<sup>29</sup>

*Other Nervous Conditions.*—Penicillin has a favorable effect on early cases of neurosyphilis.<sup>25</sup> The spinal fluid findings improve in 74 per cent of cases. In late neurosyphilis the results are also encouraging. Systemic administration usually of large doses of penicillin has been used in most cases. Intrathecal injection does not seem to have any particular advantages, and in large doses severe reactions have been reported.<sup>16</sup> Penicillin has been tried in a number of other diseases of the nervous system, including tuberculous meningitis, brain tumor,<sup>5</sup> multiple sclerosis, amyotrophic lateral sclerosis and cerebral degeneration, without any evidence that it affects the course of the disease.<sup>11</sup>

#### SUMMARY

The sensitivity of the infective organisms to penicillin is the guide to the concentration of the drug necessary in the spinal fluid for control of any disease of the central nervous system. By systemic administration alone

concentrations as high as 0.3 Oxford units/cc. may be attained in cases of meningitis, although in normal individuals little, if any, penicillin reaches the cerebrospinal fluid. Higher concentrations may be obtained by intrathecal injection of 10,000 Oxford units. A better distribution of penicillin is gained by cisternal than by lumbar injection, but the latter is a much safer procedure. Large doses of penicillin administered intrathecally are likely to cause meningeal or neural reactions in the form of fever, pleocytosis, radiculitis, convulsions, coma and even death. The therapy for the specific diseases is discussed.

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## TRAUMATIC RUPTURE OF THE SPLEEN

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TRAUMATIC RUPTURE of the spleen is not an uncommon intra-abdominal accident. Because of the great importance of early diagnosis and proper treatment, because of the diagnostic and therapeutic difficulties in certain atypical cases, and because the increased incidence of this condition is both apparent and real, it seems worth while to briefly review certain important aspects of the problem. Most reports in the literature deal with one or two cases. Such reports convey the impression that the incidence is much lower than is actually the case. Wright and Prigot<sup>1</sup> found that one out of every 666 accident cases admitted to the Harlem Hospital, of New York City, suffered from a ruptured spleen. Roettig, Nusbaum and Curtis<sup>2</sup> found splenic rupture to be present in one out of every 920 accident admissions to the University of Ohio teaching hospital.

The incidence of splenic rupture has become more apparent as diagnosis has improved; however, there is little doubt that the increase is also a real one, due to a larger number of traumatic incidents resulting from motor accidents, industrial injuries, and injuries received by both civilians and soldiers as a result of war. Of special importance is the fact, emphasized by Zabinski and Harkins<sup>3</sup>, that in approximately one out of seven cases of splenic rupture the serious hemorrhage is of the secondary type. This now well-established clinical syndrome is especially treacherous and deserves further emphasis in the literature. Splenic rupture is the most common as well as one of the most serious closed intra-abdominal injuries due to trauma. Even in cases where the only intra-abdominal injury is splenic rupture the prognosis is grave, unless diagnosis and treatment are both early and accurate. The frequency with which such lesions are associated with other traumatic injuries make the correct diagnosis and management more difficult and increases the mortality rate. In civilian life, splenic rupture is seen more frequently in closed intra-abdominal injuries. Our impression is that in battle casualties splenic rupture is due in a higher percentage of cases to penetrating intra-abdominal wounds. In cases of obvious penetration of the peritoneal cavity, the surgeon is always obligated to explore the cavity, whereas, in closed injuries, especially in cases with severe associated lesions, it is likely to be more difficult to know the proper course to follow. The type and relative frequency of various associated lesions has been pointed out by Wright and Prigot, and by Roettig, Nusbaum and Curtis, as shown in Tables II and III.



TRAUMATIC RUPTURE OF SPLEEN

ANATOMY AND PHYSIOLOGY

A few pertinent facts regarding the anatomy and physiology of the spleen are of special benefit in enabling one better to properly manage the cases being considered. The spleen is a very vascular organ composed of friable lymphoid tissue held together by a network of thin fibrous

TABLE I  
INCIDENCE OF RUPTURE OF THE SPLEEN IN CASES OF SUBCUTANEOUS ABDOMINAL INJURIES  
(Wright and Prigot)<sup>1</sup>

	No. of Cases	Percentage
Subcutaneous Rupture:		
Spleen.....	30	47.6
Liver.....	18	28.6
Intestines.....	11	17.5
Mesentery.....	3	4.7
Pancreas.....	1	1.6
	63	100.0

TABLE II  
ASSOCIATED INJURIES IN 22 CASES OF SPLENIC RUPTURE  
(Roettlig, Nusbaum and Curtis)<sup>2</sup>

Type of Injury	Incidence
Fractured ribs.....	5
Hemothorax.....	3
Fracture of extremities.....	3
Contusion of pancreas.....	1
Ruptured kidney.....	2
Retroperitoneal hemorrhage.....	1
Ruptured liver.....	2

TABLE III  
ASSOCIATED INJURIES IN 30 CASES OF SPLENIC RUPTURE  
(Wright and Prigot)<sup>1</sup>

Associated Lesions	No. of Cases
Fractured ribs.....	10
Broken bones (simple or compound fractures).....	8
Lacerated kidney.....	6
Hemothorax, pneumothorax, lacerated lung.....	4
Cerebral complications, fractured skull, lacerated brain.....	3
Ruptured liver.....	3
Ruptured Urinary bladder.....	1
Ruptured diaphragm.....	1

trabeculae and a thin fibrous capsule. The organ is almost entirely surrounded by peritoneum, being suspended by two of its folds, the phrenico-splenic and gastrosplenic ligaments. The splenic artery is the largest branch of the celiac axis, and, with the exception of the renal vessels, is the largest visceral artery in this region of the body.<sup>4</sup> Michels called attention to the fact that the position of the splenic artery is as variable as is that of the cystic artery<sup>5</sup>.

The spleen being suspended in the left upper quadrant, is protected to a certain extent by the cushioning effect of the surrounding structures—the diaphragm superiorly, the stomach and intestines medially and inferiorly, and by the lower chest wall anteriorly. This mechanism of suspension, while protecting the organ to a certain extent, also permits it to be fractured by *contrecoup* as well as by direct violence in certain instances.

The pathologically enlarged spleen, regardless of the cause of the enlargement, has no such protection, and the liability of such spleens to rupture from relatively mild trauma is well known.

The celiac plexus supplies autonomic fibers to the spleen. Stimulation of these fibers causes contraction of the organ to occur. There still remains much to be learned regarding the physiology of the spleen. During the past two decades our knowledge concerning the physiology of the spleen has been greatly augmented due to the studies of Barcroft<sup>6</sup>, Doan, Curtis and Wiseman<sup>7</sup>, Mann<sup>8</sup>, and Holman<sup>9</sup>. Three of its functions which are well-established are as follows: The formation of lymphocytes in the malpighian corpuscles; the destruction of formed elements of the blood; and the storage of blood<sup>10</sup>. This blood reserve may be drawn into the circulation during periods of emergency. It is known that the spleen undergoes contraction during periods of asphyxia, exercise, hemorrhage and emotional excitement. Barcroft and Nisimaru have demonstrated that the spleen is constantly contracting and expanding at intervals of approximately 30 to 60 seconds. These changes in splenic volume are reflected as minor changes in the mean blood pressure. It is generally believed that removal of the spleen has no detrimental effect on the general health or growth of the individual.

#### DIAGNOSIS

The fact that no single sign is pathognomonic of rupture of the spleen has been pointed out repeatedly. In most cases the diagnosis is made from a history of injury to the left side, followed by signs of peritoneal and diaphragmatic irritation coupled with a clinical picture of hemorrhagic shock.

The most frequent early findings are those of abdominal pain associated with tenderness and rigidity. These findings may be limited to the left upper quadrant of the abdomen, or there may be generalized abdominal findings. Pain in the left shoulder region, due to irritation of the diaphragm, is a fairly common symptom. This is often referred to as Kehr's sign. An area of increased dullness to percussion in the splenic region, Ballance's sign,<sup>12</sup> while not present in all cases, certainly should be looked for. In some instances a definite fluid wave has been demonstrated prior to operation. The signs of hemorrhagic shock found in splenic rupture are no different from those produced by a sudden extensive loss of blood in any other region. There may be pallor, cold clammy skin, mental confusion, a normal or subnormal temperature, tachycardia, and a falling blood pressure. In some instances, due to vasoconstriction, the body is able to com-

pensate for a rather extensive loss of blood before findings of pronounced shock are evident.

Roentgenologic examination is likely to show an area of increased density in the left upper abdominal quadrant, and there may or may not be an elevation of the left diaphragm<sup>13</sup>. Examination of the peripheral blood usually shows a leukocytosis and a gradually developing anemia.

In questionable cases, some authors have advised a diagnostic abdominal paracentesis to demonstrate the presence of blood in the peritoneal cavity. This is not always a reliable procedure, for in some instances this method will lead one away from the correct diagnosis by failing to demonstrate an extensive accumulation of blood walled-off by the omentum and viscera.

Three cases, each serving to emphasize different problems in the management of splenic rupture are reported briefly.

#### CASE REPORTS

Case 1.—C. S., a combat soldier, was admitted to the hospital complaining of pain in the right lower quadrant of the abdomen. The patient began to experience generalized abdominal pain of moderate severity 24 hours prior to admission. He became nauseated and vomited once. Six hours before admission the pain became localized in the right lower quadrant. There was no history of a previous similar attack.

The past history revealed that one week before admission the patient had been knocked down by the concussion of a shell burst on the Anzio beachhead. The concussion was so severe that the patient was thrown against the ground about ten feet from where he was standing. He fell upon his left side. The patient felt shaken up and slightly bruised but did not feel that he was seriously injured. Following this incident he spent three days in an Evacuation Hospital before returning to his unit. During the three days following the explosion the patient felt faint on three occasions, but never fainted. He experienced no pain in the left shoulder or in the abdomen while at the Evacuation Hospital.

*Physical Examination.*—Temperature 100° F., pulse 80, and respiration 24. *Chest:* Scattered râles present over left chest posteriorly. *Abdomen:* Tenderness and slight rigidity in right lower quadrant, most marked at McBurney's point. The patient was tender on the right side by rectal examination. *Laboratory Data:* Chest film—Normal. W. B. C. 16,700; R. B. C. 4,000,000; hemoglobin 85 per cent; lymphocytes 28 per cent. Urine normal. *Preoperative Diagnosis:* Acute appendicitis.

*Operation.*—A right muscle-splitting incision was made. The peritoneum was opened and a large amount of fluid which had the appearance of whole blood welled-up through the incision. Suction was used and the appendix was delivered. The distal half of the appendix was edematous and distended. Appendectomy was performed, the stump being inverted. There was no evidence of a Meckel's diverticulum, and the abdomen was closed. It was felt that the blood in the abdominal cavity represented both an old and a recent hemorrhage. In view of the patient's injury one week previously, a tentative diagnosis of delayed hemorrhage from traumatic rupture of the spleen was made. The appendectomy had been performed under a low novocaine spinal anesthetic. Ether and oxygen were given, and a left rectus incision was made. The spleen was examined and found to be torn at the lower pole. Large clots were present and some fresh bleeding was occurring. Splenectomy was performed without difficulty. During the operation, 2000 cc. of sanguineous fluid which had the appearance of whole blood was aspirated from the abdominal cavity. The blood pressure remained at a normal level throughout the procedure; however, 500 cc. of plasma was given during the operation and 500 cc. of whole blood was given after the completion of the operation.

*Pathologic Examination:* The appendix, in its distal half, is extended and the wall is edematous. There is no fibrin on its surface. The lumen is obstructed by a fecolith.

The spleen was sent to a General Medical Laboratory. The report submitted by Lt. Col. Tracy B. Mallory, M.C., was as follows: Specimen consists of a spleen, measuring 10 x 8 x 5 centimeters. Capsule is grey-brown and slightly wrinkled. Beneath the splenic notch is a splenic enlargement covered by intact capsule, but appearing dark purple in color. There is a small linear tear at the hilus, two centimeters in length. On cut-section the splenic pulp is red-brown in color except for an area, 4 x 1.5 centimeters, lying beneath the discolored portion of the capsule. This area is deep purple in color, and soft in consistence. A small hemorrhagic area one centimeter in diameter is found in the pulp in the upper pole.

*Microscopic Examination:* Sections show focal areas of parenchymal and subcapsular hemorrhage. There is an early polymorphonuclear response in some regions and a small zone of infarct necrosis, probably due to the presence of ischemia, is seen. *Pathologic Diagnosis:* Ruptured spleen. Multiple hematomata of spleen.

*Postoperative Course:* The patient developed bronchopneumonia following operation. This responded promptly to sulfadiazine, and his recovery was otherwise uneventful. Three weeks following operation the patient had recovered entirely and the blood studies were normal.

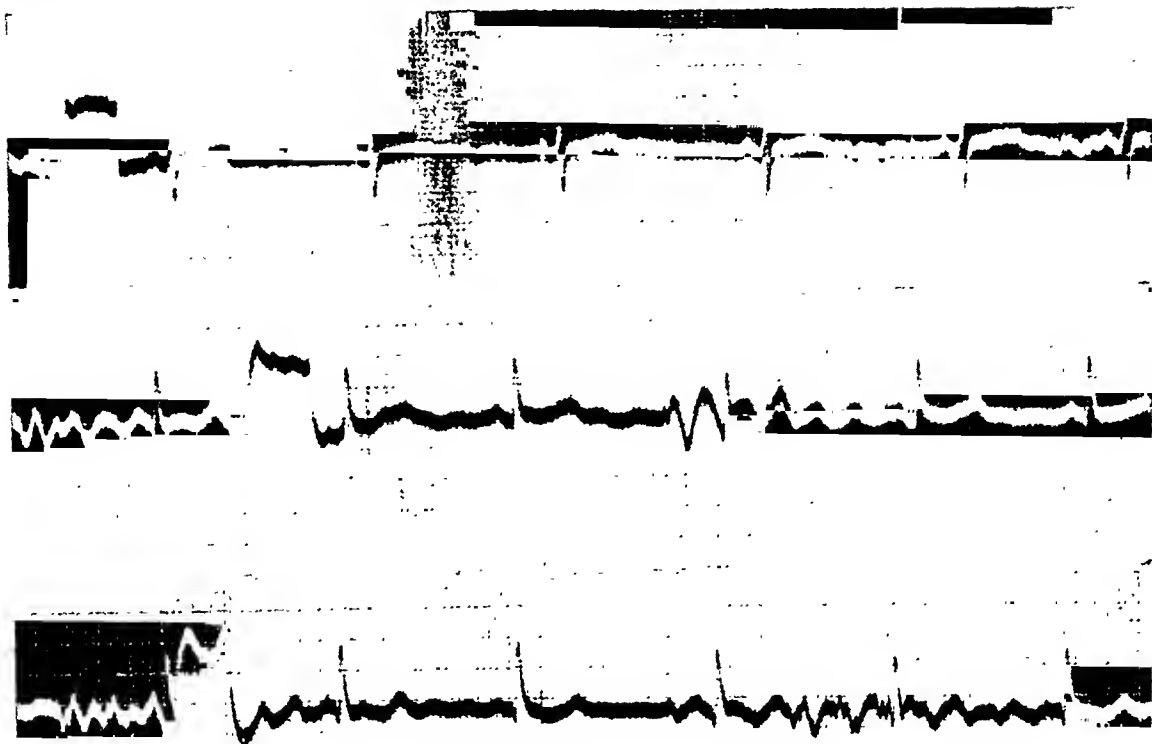
**Case 2.**—J. C., a well-developed young soldier, while working as a lineman fell from a pole after receiving an electrical shock. The patient struck his head and left shoulder against the ground at the time of the fall. At 4:20 P. M., one-half hour after the fall, this man was brought to the hospital.

*Physical Examination:* The findings of severe traumatic shock were present, and it was impossible to obtain a blood pressure reading or to palpate the pulse on admission. There was a superficial electrical burn of the right hand and penis. Over the occipital region was a deep irregular laceration, approximately 14 centimeters long. The patient was unable to move his legs, and anesthesia was present below the nipple level. The patient was placed in the shock position and was given 750 cc. of plasma, followed by 500 cc. of blood. He was seen in consultation by Major William Beswick, M.C., neurosurgeon, who felt that it was best at the time to apply simply a sterile dressing to the shaved scalp and to delay, for the time being, any operative repair.

The patient was moved by litter a short distance to the Recovery Ward, and the blood pressure again fell to 60/30. The pressure returned to 110/70 following the administration of 1,000 cc. of whole blood and another 250 cc. unit of plasma. Examination at this time showed the patient to have no complaints except that of some discomfort about the scalp wound and in the region of the left shoulder, upon which he had fallen. The abdomen was soft, and there was no evidence of fracture of any of the long bones.

At 3 A. M. the blood pressure had fallen to 80/40, and the patient again showed all the signs of severe hemorrhagic shock. The abdomen was soft, and no masses could be felt. There was no fluid wave; however, shifting dullness was present in the left flank. A diagnosis of rupture of the spleen with severe intra-abdominal hemorrhage was made. It was realized that the patient also suffered from a lesion of the spinal cord at the level of D-4, and from a severe scalp laceration.

*Operation.*—Celiotomy was done without any anesthetic agent being necessary because of the cord injury. Oxygen and blood replacement therapy were continued throughout the operation, which was begun with the patient in a state of shock. Blood was not apparent when the abdominal cavity was first opened. After the omentum was withdrawn the left side of the abdomen was found to contain a large amount of clotted and unclotted blood. The spleen was lacerated in two places and a retroperitoneal hematoma was present in the left renal area. Splenectomy was performed and the abdomen was closed with through-and-through heavy silk sutures. At the end of this procedure the blood pressure had returned to 102/70. The scalp was then repaired, local anesthesia being



GRAPH 1.—E. K. G. tracing (on sixth postoperative day) showing evidence of severe myocardial damage characterized by atrioventricular fibrillation flutter and auriculoventricular block.



GRAPH 2.—E. K. G. (one month after first E. K. G.) curve is approaching that of a normal tracing, indicating marked improvement in the cardiac mechanism.

used. During the course of the operation 1,000 cc. of blood and 500 cc. of plasma were administered.

One week after splenectomy a laminectomy was performed by Major William Beswick, M.C. At the site of the compression fracture of the fourth dorsal vertebra the spinal cord was found to be partially severed due to trauma produced by fragments of bone. The patient withstood the operation satisfactorily; however, motor function and sensation were not improved as a result of the cord section. The patient was eventually evacuated to the Zone of Interior.

**Case 3.**—S., a 14-year-old school boy, was admitted to the hospital one hour after his school bus had been struck by a train. The pulse and blood pressure were not obtainable on admission; however, after the patient had been placed in the shock position and given intravenous fluids the pressure was found to be 105/65. Examination revealed a five-centimeter laceration of the scalp, abrasions of the left chest and abdomen, and superficial abrasions of the extremities. Tenderness was present in the left upper abdominal quadrant. There was slight rigidity of the left rectus muscle in the upper abdomen. A normal urine specimen was obtained.

It was felt that the patient probably had a ruptured spleen, and he was sent to the operating room by way of the Roentgenologic Laboratory. No fractures of bones were found. In the plain film of the abdomen the left upper quadrant was more dense than normal. The psoas shadow on the left side was obliterated. This was interpreted as being suggestive of hemorrhage from a ruptured abdominal viscus. The chest film was normal.

The patient was taken immediately to the operating room. The movement of the patient apparently affected the blood pressure adversely, as the systolic pressure fell to 84 as the operation was begun. A 500-cc. blood transfusion was administered during the operation and another similar transfusion was given after the operation.

**Operation.**—The abdomen was explored through a left rectus incision. The abdominal cavity seemed to be filled with blood and fresh bleeding was seen to be occurring from the spleen. The pedicle was compressed with the left hand and the incision was enlarged by making a short lateral, or T-shaped, extension. Splenectomy was performed and the abdomen was closed without drainage after the blood had been removed by aspiration. The scalp laceration was sutured.

The postoperative course was relatively uneventful for four days. The patient was slightly distended, but passed flatus and had a normal bowel movement on the fourth postoperative day. The pulse, which was usually regular, varied between 90 and 110 much of the time. The urine at this time was normal.

On the sixth postoperative day a marked irregularity of the pulse was noted (Graph 1). The rate varied, at times being found to fluctuate between 38 and 65. A medical consultant, Dr. Lyle Motley, studied the patient at this time and felt that the arrhythmia was due to cardiac trauma at the time of the accident. It was felt that there might be a fracture of some myocardial fibers. No specific therapy was advised and the consultant felt that the prognosis would probably be favorable.

On the ninth postoperative day, because of abdominal cramps and distention associated with vomiting and constipation, a diagnosis of intestinal obstruction was made.

A right rectus incision revealed an obstruction of the lower ileum at a point where the bowel was adherent to the anterior abdominal wall. When the bowel was separated from the anterior abdominal wall an abscess containing 50 cc. of pus was opened into, and it was seen that a small perforation of the ileum had apparently existed, which had become sealed over. A purse-string suture was used to close the bowel opening. A Witzel ileostomy was done, and two rubber tissue drains were left in the abdomen and brought out *via* stab wounds, one drain leading to the site of the abscess cavity near the abdominal wall, and the other being placed in the pelvis.

There was an unexplained hematuria for a few days following the operation. The urine returned to normal without any specific therapy. The course after this was uneventful except for a small abscess in the abdominal wall, which was drained under local anesthesia. The patient left the hospital approximately eight weeks after admission. At this time, his abdominal wall was well healed, the pulse rate was normal, and studies of the blood, urine and electrocardiogram were normal (Graph 2).

DISCUSSION.—Each of the cases presented serves to emphasize certain important problems in the diagnosis and treatment of splenic rupture. Case 1 came to the hospital with a diagnosis of acute appendicitis, which was verified at operation. The finding of a large collection of blood in the peritoneal cavity, coupled with the history of being thrown against the ground one week previously, made the diagnosis of splenic rupture with delayed hemorrhage seem likely. It is believed that the spleen was injured at the time of the shell concussion one week prior to the development of acute appendicitis. Hemorrhage no doubt occurred at the time of this injury and was probably responsible for the patient feeling quite faint on three occasions, although he never actually fainted. It seems likely that additional blood was being lost from the splenic rupture even though no symptoms were present which could be attributed directly to this. Blood in the right colic gutter can, without question, produce pain which simulates acute appendicitis; however, examination of the appendix showed it to be definitely inflamed. This then, is a case of splenic rupture with delayed hemorrhage which was operated upon during the latent or silent period, the condition being brought to our attention because the patient chanced to develop acute appendicitis at the same time.

The syndrome of delayed hemorrhage from splenic rupture is important, dangerous, and not nearly so uncommon as one might be led to believe from the paucity of material on the subject found in the literature<sup>13, 14, 15</sup>. In most cases there is a history of some type of trauma to the splenic region followed later by the findings of peritoneal irritation and hemorrhagic shock, these findings being due to the presence of the blood lost into the peritoneal cavity. The blood in the abdominal cavity most commonly causes pain, tenderness and rigidity in the left upper quadrant, but these findings may be generalized, and in one reported case the physical signs were present only in the right lower quadrant. The blood from the ruptured spleen may cause diarrhea or constipation due to ileus. Distention may be present. McIndoe<sup>14</sup>, in 1932, studied 46 cases representing cases collected from the literature, and his own case. He stimulated much of the subsequent interest in the subject. Recently Zabinski and Harkins<sup>3</sup> have made a comprehensive review of the literature and summarize the findings gained from a study of 179 cases of delayed hemorrhage from splenic rupture.

Case 2 shows the importance of considering the spleen as a source of internal hemorrhage even in the absence of pain, tenderness or rigidity of the abdomen. Shifting dullness in the left flank was demonstrated in this case. The fact that blood was not visible when the abdomen was opened,

until after the omentum was withdrawn, stresses the fallacy of relying upon abdominal paracentesis as a criterion for diagnosis.

Cases 2 and 3 were both operated upon with the patients in a state of shock. The operation was considered imperative and was, in fact, a part of the treatment for shock, as it was necessary to control the active bleeding. In both instances blood was given during and after the operation. These cases also stress the necessity of performing major surgery to preserve life even in the presence of such severe associated injuries as fracture of the dorsal spine with partial section of the spinal cord and severe trauma to the myocardium. The successful treatment of such cases calls for surgical intervention combined with immediate blood replacement therapy.

A few cases are reported where minor splenic fractures were successfully treated by tamponade or suture, but these methods offer far less security from future hemorrhage than does splenectomy. Studies of reported cases reveal a surprising number of wound disruptions occurring as complications in these cases. This has frequently been secondary to pancreatic injury which occurred at the time of the splenectomy. Such injuries can best be avoided by the individual ligation of splenic vessels near the hilum and the avoidance of mass ligatures which may inadvertently include some pancreatic tissue.

#### SUMMARY AND CONCLUSIONS

1. The incidence of traumatic rupture of the spleen is believed to be increasing due to more accurate diagnosis and to an increase in traumatic accidents encountered by civilians and soldiers.
2. The anatomy and physiology of the spleen are reviewed as related to the management of splenic rupture.
3. Traumatic splenic rupture is the most frequent, as well as one of the most serious, subcutaneous intra-abdominal injuries.
4. The importance of recognition of the syndrome of splenic rupture with delayed hemorrhage is emphasized.
5. Splenectomy combined with adequate blood replacement therapy is the treatment of choice, and this should be instituted as soon as the diagnosis is reasonably established.

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# ACUTE HYPERTENSION WITH SODIUM PENTOTHAL ANESTHESIA IN NEUROLOGIC SURGERY

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THE USE OF SODIUM PENTOTHAL as a surgical anesthetic agent continues to increase in popularity. This is especially true in cases where extensive muscular relaxation is not required. For this reason, many neurosurgeons are using intravenous sodium pentothal anesthesia in all intracranial surgery, usually with the exclusion of suboccipital and cervical exposures. Despite the fact that many of these operations are quite lengthy—frequently lasting three and four hours—no adverse criticism has been brought forth. There are, however, very few reports of any unusual reactions that may occur in its use in neurologic surgery.

One particular phenomenon that has occurred with surprising frequency is an elevation of blood pressure occurring during the subtemporal approach for a retrogasserian neurectomy when performed under sodium pentothal anesthesia. Woodall and Goodman<sup>21</sup> have noted this reaction but felt that it was due to stimulation of the gasserian ganglion. Lundy<sup>11</sup> mentions that he has noted vascular hypertension once or twice in intracranial surgery when pentothal anesthesia was used. The type of case or procedure, however, is not described. The vascular effect most frequently mentioned has been a mild hypotension correlated with the rapidity and amount of pentothal used.<sup>13, 17</sup> This was thought to be due to a reduced sympathetic activity.<sup>12</sup> Other signs of a state of sympathetic hypoactivity is a reduced peripheral resistance<sup>16</sup> and raised skin temperature.<sup>2</sup> Allen, Lundy and Adson<sup>2</sup> used intravenous pentothal as a preoperative indication for sympathectomies. They believe that it gave an accurate reflection of the fall in blood pressure that ensued after upper lumbar and splanchnic resections.

Gruber, *et al.*,<sup>8</sup> and Burstein and Ravenstine,<sup>5</sup> have shown from work on animals that the parasympathetic (cardiac vagus) system is hypersensitive during sodium pentothal anesthesia. Further evidence of autonomic hypersensitivity, noted by Bishop and Rudder<sup>4</sup> has been the repeated appearance of bradycardia during ocular enucleations only when performed under intravenous pentothal anesthesia. They felt that this was "a manifestation of the oculocardiac reflex plus the parasympathetic action of pentothal sodium."

In animal experimentation, Reynolds<sup>15</sup> failed to note a fall in blood pressure when sodium pentothal was injected slowly and just sufficiently to stop respirations. A second dose given after the return of reflexes caused an increased pulse pressure, but without "significant alteration of the systolic pressure." Draper and Whitehead,<sup>6</sup> likewise, found the blood pressure maintained at normal levels in dogs during surgical anesthesia, with a fall during

the toxic stage. After respiratory arrest had been maintained and anoxemia had developed, the blood pressure level rose.

Elevations in blood pressure have been reported with sodium pentothal anesthesia in rabbits<sup>10</sup> and dogs.<sup>7, 9</sup> An initial fall in pressure in half of the dogs was followed by a secondary rise which surpassed the control pressure in 90 per cent of the experiments. The maximum rise was 77 mm. of mercury. In some a pure rise in pressure occurred.

#### MATERIAL AND METHODS

The present report comprises observations on blood pressure changes which occurred during the subtemporal surgical approach to the retrogasserian ganglion in a group of 20 cases. In order that a control might be established, a second group of 20 cases of extirpation of herniated intervertebral disks were studied also. A series of ten consecutive cases from each group operated upon under intravenous sodium pentothal anesthesia was compared to a similar series operated upon under other anesthesia.

The method of surgical exposure of the gasserian ganglion was similar in all cases. In each instance the patient was placed in a sitting position and a vertical incision was made in the temporal region. The temporal fascia and muscle were incised, the bone was trephined and enlarged to the size of a silver dollar. After the dura mater was stripped from the floor of the middle fossa, the foramen spinosum was plugged with cotton and the middle meningeal artery cut. The dura propria was elevated from the covering of the ganglion which was incised and the retrogasserian fibers avulsed. At the completion of the avulsion, jugular compression was performed to verify hemostasis.

A routine technic in extirpation of the herniated intervertebral disks was carried out. The patient was placed in a prone jack-knife position with the trunk horizontal. The paravertebral muscles were separated subperiosteally from the spines and lamina. After excising the ligamentum flavum, the dura and nerve root were retracted medially, the annulus fibrosus incised and the greater portion of the disk removed.

Premedication consisted of .0004 to .0006 Gm. atropine sulfate in all cases, and either morphine sulfate .01 Gm. or calcium nembutal .18 to .27 Gm. These were usually administered one hour before surgery. No significant change could be correlated with the latter two drugs.

Intravenous anesthesia was always started with a 2.5 per cent solution of pentothal by syringe. After narcosis was well induced, a 1 per cent solution—usually by the slow continuous drip method—was used to maintain the desired level throughout the remainder of the procedure. Surgery usually was begun immediately after anesthesia was induced. Inhalation of either 100 per cent oxygen or oxygen plus nitrous oxide—50 per cent each—was given. In four cases in which oxygen plus nitrous oxide was used the average rise in pressure was almost identical with the cases in which only oxygen had been used. The average amount of pentothal used in the subtemporal approach

was 1.65 Gm., and in the spinal cases it was 2 Gm. The increased amount used in the latter group was due to a lengthier operative time. Supplementary fluids or stimulants were not required in any case.

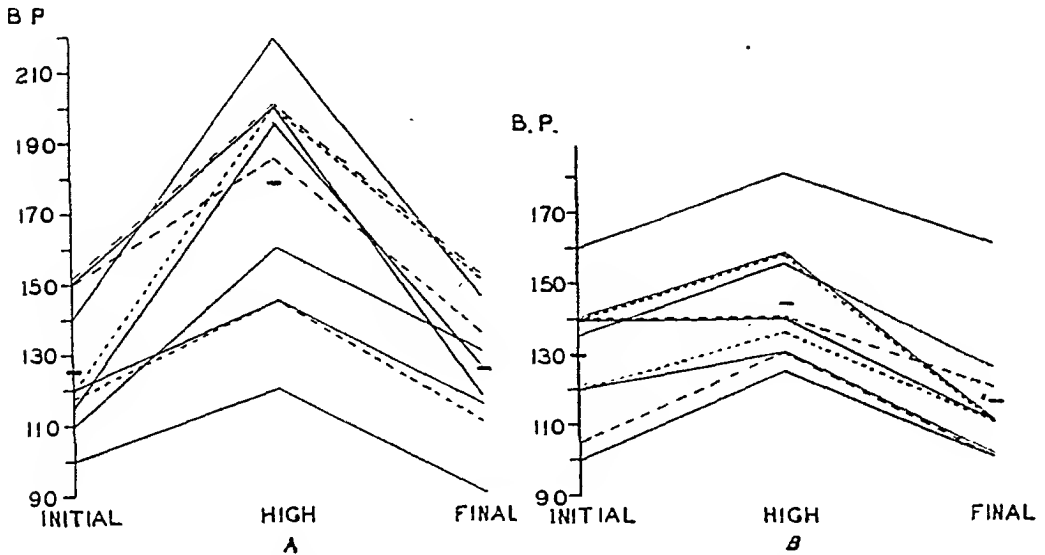


CHART 1.—Showing blood pressure readings before surgery (initial), the highest level occurring during surgery (high), and at the completion of the operation (final) for retrogasserian neurectomy by the subtemporal approach are shown.

The elevation in blood pressure under sodium pentothal anesthesia (A), may be compared with that under ether anesthesia (B).

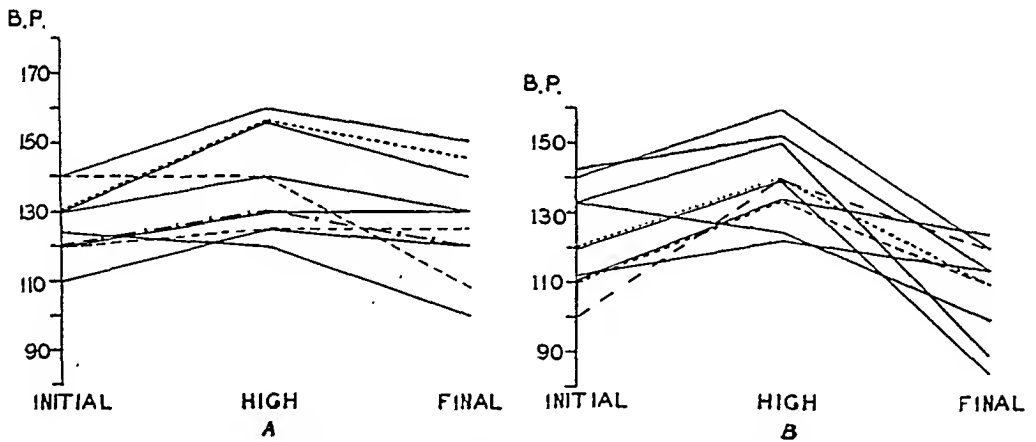


CHART 2.—Showing blood pressure levels during extirpation of herniated intervertebral disks under sodium pentothal (A) and ether (B) anesthetics are illustrated.

## RESULTS

Under sodium pentothal anesthesia there was a marked rise in blood pressure when performing the retrogasserian operation. The average rise in systolic pressure was 51.3 mm. of mercury and in diastolic pressure 32.5 mm. The elevated blood pressure was usually maintained throughout the period of intracranial manipulation and was not limited to the time during which the retrogasserian fibers were being exposed and avulsed. There was seldom an associated rise in pulse rate of any consequence. During the latter part of

the intracranial procedure the pressure began to fall and was essentially normal at the end of the operation. In several cases it was noted that the return to the preoperative level took a precipitous drop immediately after bilateral jugular compression. The changes in each case are shown in Chart 1. The initial blood pressure, that which was taken by the anesthetist prior to anesthesia, averaged 125.5/76 mm. of mercury. The average highest reading was 176.8/108.5 mm., and the average final reading was 124.5/79.0 mm. of mercury. Two points are of particular interest in these figures. First, the rise in pressure is far above that which is likely to occur either from irritation of a peripheral nerve or as a coincidental reaction. Second, the final pressure at the end of the operation was essentially the same as the preoperative level.

In the subtemporal series operated upon under ether anesthesia the average systolic elevation was 14.1 mm. of mercury. The average diastolic elevation was negligible—only 0.17 mm. As might be expected from general surgical experiences, the final blood pressure was approximately 15 mm. of mercury lower.

The results of blood pressure variations in the spinal operations are depicted in Chart 2. It is at once obvious that there are no essential differences during the operative procedures. There was a slight rise in both series done under pentothal and under ether anesthesia. The average rise in the former was 11/8.7 mm. of mercury and in the latter 17/9 mm. of mercury. A point of interest, however, is the final level. This is similar to that occurring in intracranial surgery with sodium pentothal in that the final pressure was identical with the preoperative level despite an operative time varying from 1.5 to 3 hours and an average requirement of 2 Gm. pentothal.

To obviate the effect of pentothal anesthesia upon postural vascular tension, a series of 15 patients with convulsive seizures were studied before performing a pneumo-encephalogram. Intravenous sodium pentothal was given with the patient supine. Blood pressures were taken at one to three minute intervals. No constant changes were noted during or after the induction phase; however, a slight fall in pressure was frequently noted. The patient was tilted to an upright sitting posture. Blood pressures were taken at 30°, 60°, and 90° and similarly on being lowered. There were no constant or striking changes associated with the position. Occasionally a 10 to 15 mm. fall in pressure was noted after the anesthesia was induced; a somewhat similar fall or rise ensued after the patient was placed in the sitting position.

*Discussion.*—The acute hypertensive phenomenon noted in subtemporal craniectomy procedures under pentothal anesthesia is presented both for its physiologic and clinical interest. The hypertension in some of the cases was quite striking, reaching a maximum elevation of 85 mm. of mercury. There are several important clinical factors. Gruber, Haury and Gruber<sup>9</sup> felt from their experimental work on dogs that the general systemic blood pressure elevation might be a definite contraindication for the use of this drug in cases of hypertension or cardiac damage. This would seem logical since in dogs cardiac arrhythmia was routinely produced under this anesthesia. "In those experi-

ments in which cardiac arrhythmia was not instituted by the injection of pentothal sodium, the arrhythmia could usually be introduced by increasing the blood pressure upon withdrawal of the carotid sinus reflex." In the present series, however, only one case of cardiac arrhythmia was noted under sodium pentothal anesthesia. In this case an elevation in blood pressure of 30 mm. Hg. was followed by a cardiac fibrillation. This occurred after two hours of anesthesia. The fibrillation lasted about five minutes but was insufficient to produce gross signs of circulatory embarrassment. The cardiac rhythm returned to normal with a sudden drop in blood pressure. Since this was at the end of the surgical procedure, at which time the usual drop occurred, it was not possible to determine whether the fall in pressure mitigated the fibrillation or whether the fibrillation caused the fall in pressure.

Despite the fact that many of the patients in this group had mild generalized arteriosclerosis, with slight cardiac enlargement, their general post-operative recovery appeared smoother than the cases performed under ether anesthesia.

An important point noted has been in the normalcy of the blood pressures in both groups operated upon under pentothal anesthesia. This was present despite occasional lengthy operating time and use of rather large doses of sodium pentothal, and would tend to refute any detectable deleterious effect of pentothal upon the circulatory or cardiac system.

Several authors have suggested that pentothal should not be used in cases of shock. However, the findings in the present cases, particularly the normal blood pressures at the end of the operative procedures would tend to suggest a converse opinion. This factor has been substantiated (Pender and Essex<sup>14</sup>) by showing a delayed development of shock and death in dogs under pentothal as compared to ether anesthesia. Adams and Gray<sup>1</sup> verify this clinically.

The cause of the hypertension in the present cases is not clear. The possibility of irritation to the trigeminal nerve does not appear likely since the elevation in blood pressure was usually encountered before the nerve was reached and persisted to a slight extent after all the fibers were avulsed. If pain alone were a factor, a similar elevation would be expected upon retraction of the sensory roots during disk operations and also on cutting the trigeminal root by the suboccipital approach. This did not occur. It is more probable that an hypersensitivity of the cerebral vasomotor centers takes place under pentothal anesthesia. Parasympathetic overactivity has been shown in experimentation on cats.<sup>5</sup> In the discussion of the hypertension found in dogs<sup>9</sup> no postulation as to the underlying mechanism was made. The possibility of increased intracranial pressure *per se*, due to retraction and pressure upon the unopened dura, has been considered but has been discarded for several reasons: (1) A lowered intracranial pressure has been shown to be present under sodium pentothal anesthesia.<sup>10, 21</sup> (2) Intracranial pressure is lessened at the time of incising the sheath of gasserian ganglion with the escape of cerebrospinal fluid. (3) Hypertension was not present in those cases operated upon under ether anesthesia.

# SUMMARY

A definite acute arterial hypertension has been noted during the sub-temporal approach to the gasserian ganglion when performed under sodium pentothal anesthesia. The average elevation in blood pressure in a series of ten consecutive cases was 51.3/32.5 mm., of mercury. Under ether anesthesia such an elevation does not occur—the average in a similar series being 141.1 mm. of mercury. In a comparative series of pentothal and ether anesthetics for the extirpation of herniated intervertebral disks, no specific elevation of blood pressure was seen. The average pressure being 11/8.7 and 17/9 mm. of mercury, respectively.

The final blood pressure in both series, however, was higher when pentothal was used, thus, suggesting that operative or postoperative shock is less likely to occur under pentothal anesthesia.

The possibility of a postural hypertensive effect under pentothal sodium was eliminated. It appears more likely that an increased sensitivity of the central vasomotor centers occurs during pentothal anesthesia. Since the retraction of the temporal lobe probably results in a rather widespread pressure or irritative effect, the site of the vasomotor stimulation is not known.

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Note: The cases used in this report were obtained largely from the neurologic service of Dr. A. E. Walker.



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